A-canal fish entrainment during 1997 and 1998 with emphasis on endangered suckers

Under grant number 8-FG-20-16580
Submitted to:

Mr. Mark Buettner
U.S. Bureau of Reclamation
Klamath Basin Area Office
6600 Washburn Way
Klamath Falls OR 97603

New Earth/Cell Tech: Research and Development
Brandt Gutermuth and Elizabeth Pinkston
1410 S. 6th Street
Klamath Falls, Oregon 97601

and

Natural Resource Scientists, Inc.
Dave Vogel
P.O. Box 1210
Red Bluff, California 96080

March 2000

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF TABLES

APPENDIX FIGURES

INTRODUCTION

The Upper Klamath Lake system (referred to henceforth as Upper Klamath Lake) in south-central Oregon covers approximately 125 mi^2 and has the greatest surface area of any natural water body in Oregon (Gearheart et al. 1995). Due to its naturally high inflow of nutrients and its large watershed area (3,784 mi^2), Upper Klamath Lake has historically been very productive, however, land-use and hydrologic alterations during the 1900s have increased the lake's productivity to the point where large-scale blooms of *Aphanizomenon flos-aquae* dominate the summer plankton and where water quality is often mediated by the occurrence of this species (Kann and Smith 1993). Today poor water quality events often affect the survival of Upper Klamath Lake's aquatic community.

The Lost River sucker (*Deltistes luxatus*) and the shortnose sucker (*Chasmistes brevirostris*) are endemic to Upper Klamath Lake and the Klamath Basin of south central Oregon. These species were historically numerous, but fish monitoring in the 1980's indicated that populations were declining and that recruitment of suckers to adult-size was inconsistent (Buettner and Scoppettone 1990; Bienz and Ziller 1987). In 1988, both these species were protected under the Endangered Species Act (ESA) as endangered species (USFWS 1988). According to federal law, the U.S. Fish and Wildlife Service (Service) administers the ESA and ensures its lawful application. The Service ensures that private and government entities avoid "taking" endangered species and often requires research to determine the level of "take" under current operations.

The A-canal, a large irrigation canal (up to 1100 ft^3/s) at the southern end of Upper Klamath Lake, is owned by the U.S. Bureau of Reclamation (Reclamation) and is operated by the Klamath Irrigation District (KID). The A-canal is part of the Klamath project which serves 80,000 acres of downstream irrigable land and provides water for algae harvest at New Earth's B- and C-canal algae harvest facilities (Mr. Dave Solem, KID manager, as cited in Vogel 1997). The canal intake (headworks) is positioned near the lake's natural Link River outflow, on the east bank, upstream of PacifiCorp's Link River dam power plant intakes (Figure 1). The A-canal is the largest unscreened diversion in the state of Oregon and natural resource agencies are concerned over the potential effects of this water diversion on Upper Klamath Lake fishery resources, including federally listed sucker species and trophy rainbow (redband) trout (*Oncorhynchus mykiss*).

The Oregon Department of Fish and Wildlife (ODFW) and the U.S. Fish and Wildlife Service have jurisdiction in the protection of Upper Klamath Lake aquatic life. The Service has primary authority for protection of the lake's two federally listed sucker species and ODFW has the responsibility to protect all fish, including endangered suckers, in state waters.. The federal recovery plan for Lost River and shortnose suckers (USFWS 1993) includes objective #225. "To reduce losses of fish to water diversions" and #2251 "To assess losses of fish due to water diversions." ODFW's legal authority for requiring irrigation canal screening is derived from Oregon State statute 498.2.48.

In response to concerns over fish entrainment into the A-canal, Reclamation initiated post-irrigation canal salvages of endangered fishes in 1989 and funded the Oregon State University (OSU) to evaluate entrainment into the A-canal during 1990 and 1991. During these two OSU study years, larval suckers were collected in drift nets run at the front of the A-canal headworks and quantitative estimates of larval sucker entrainment were made (Harris and Markle 1991, Markle and Simon 1993). The results of these efforts indicated that endangered suckers did enter the A-canal, but the magnitude and effect of the entrainment on the population was uncertain. However, recent A-canal water quality data (Gutermuth et al. 1998) suggest that survival of A-canal entrained fish is minimal.

In 1992, under section 7 of the ESA, the Service issued a Biological Opinion (BO) concerning the long-term operations of Reclamation's Klamath Project (USFWS 1992). This BO addressed concerns over the potential impacts of endangered sucker losses to the A-canal with the following reasonable and prudent alternative (RPA).

> "Reclamation shall implement a method to reduce entrainment of larval, juvenile, and adult Lost River and shortnose suckers into the A-canal within 5 years of issuance of this Biological opinion" *(by July 22, 1997).*

In 1996, the Service issued a BO on Reclamation's permitting of PacifiCorp and New Earth Company operations in the Klamath Basin (USFWS 1996). This consultation required that New Earth conduct actions to prohibit suckers greater than 75 mm fork length (FL) from entering the east and westside Link River hydroelectric power canals by June 1997. An amendment to the 1996 BO, however, allowed New Earth to delay its entrainment reduction activities and provided more time for collection of additional entrainment information and coordination of Upper Klamath Lake entrainment reduction efforts on the A-canal and Link River hydro-facility canals. The amendment supported the efforts of the Reclamation-led "Upper Klamath Lake Entrainment Reduction Working Group" to comprehensively address entrainment issues at these two associated locations.

In lieu of eliminating A-canal fish entrainment, Reclamation has been working towards their 1997 entrainment reduction requirement by conducting fish screening feasibility studies and by providing funding for the KID to investigate entrainment reduction options. A final report, entitled "*Preliminary investigation of fish entrainment into the A-canal on Upper Klamath Lake*," by Dave Vogel, was completed for the KID and Reclamation in August of 1997. This report detailed difficulties which make the screening of the A-canal more complex than similar-sized diversions at other locations. Chief among these obstacles are the general physical attributes of the A-canal withdrawal location and the tremendous debris/algae load in Upper Klamath Lake. Hydraulic conditions at the A-canal headworks vary greatly with the elevation of Upper Klamath Lake and the canal itself has no practical avenue for by-pass of fish back to the lake. If fish were efficiently screened from the A-canal, many of these would be subsequently entrained into the downstream un-screened Link River power canals (Figure 1). In addition, the large debris/algae load in Upper Klamath Lake not only can clog most screens, but can also result in the degradation of water quality so that conditions become life threatening for aquatic resources (Kann and Smith 1993; Bellerud and Saiki 1995; USGS 1996; Kann 1997). In fact, poor water quality has resulted in lake fish kills during three of the last five years (Buettner 1997; pers. obs.). Given these poor water quality conditions (low dissolved oxygen concentrations, high pH, high un-ionized ammonia levels, and high temperature) fish entrainment problems are likely exacerbated as fish are incapacitated or move in an effort to leave stressful conditions.

While efforts are ongoing to determine acceptable solutions to achieve A-canal entrainment reduction, or to mitigate its losses, Reclamation continues to collect information which will aid in meeting their RPA to enact entrainment reduction on the A-canal. This study was funded by Reclamation and initiated in 1997 to provide information on the magnitude, timing, and duration of entrainment of all life-stages of Upper Klamath Lake fishes (with emphasis on endangered sucker species) at the A-canal. Fish entrainment is characterized in size classes of <75 mm, 75-150 mm, and >150 mm FL to meet the guidelines of the 1996 BO on New Earth and PacifiCorp operations (USFWS 1996) and to generally represent sucker age classes of age-0, age-1, and age-2+ fish. In addition, environmental conditions were recorded during the study period to review potential cues which might affect fish movement. Data on the physical condition of entrained fish was also compiled to determine the likelihood of survival of these fish had they not been entrained.

MATERIALS AND METHODS

OVERVIEW

Juvenile/adult sampling of entrained fish took place at the headworks of the A-canal during the 1997 and 1998 irrigation seasons. An 8-ft diameter rotary screw trap and a 60 ft^2 fyke net were used during both years. Screw trap and fyke net studies were conducted approximately 120 ft (36.6 m) downstream of the A-canal headworks.

Concurrent with A-canal studies, the New Earth Company was conducting similar entrainment research on the hydropower canals of the Link River (Gutermuth et al. 1999). Data collection and database management were developed in a format which allowed for comparison between A-canal and Link River studies to assess potential trends (e.g., timing and species composition). Because an additional year of data was available from Link River studies, and because sampling methods were substantially different between sites, quantitative comparisons between sites were not included in this report. Water quality data were provided by Reclamation, which maintains continuously recording water quality multiprobes at the headworks. Monitored parameters included dissolved oxygen concentrations (DO), pH, temperature, and specific conductivity. Secchi depth measurements were taken on a daily basis as an indicator of algal density.

Sampling effort

Both the screw trap and the fyke net were fished continuously for up to seven days per week in 1997 and five days per week in 1998. In both years, sampling began shortly after the start of the irrigation season and early-April (approximately April 1) filling of the A-canal. Collections were begun in mid-May 1997 and mid-April 1998, and continued until canal closure in mid-October. In 1997 however, construction of the fyke net structure was not completed until late June, and fyke net fishing began June 30. Daily catch data were also separated into day and night catch (dawn to dusk, dusk to dawn) to evaluate diel fish entrainment patterns. Daily and weekly catch summaries were then developed based on 24-hr daily sample periods which ran from approximately dusk to dusk (~ 18:30-18:30), and weekly periods which ran from Monday to Monday (screw trap set on Sunday evening).

Due to the magnitude of their numbers and reduced screw trap efficiency at small sizes attributable to trap and live box screen mesh sizes, only fish $\geq$ 35 mm fork length (FL) were effectively sampled. In 1997, blue chubs (*Gila coerulea*) were not enumerated until 40 mm FL. Biological data collection included species, fork length, physical condition (e.g., noting of wounds, fungus, parasites, etc.), and final disposition (alive or dead). These data were recorded using field codes, which are presented in Table 1.

All catostomids were measured. For non-target species (species other than suckers), a representative sub-sampling of lengths was conducted when more than 30 individuals were collected. Sub-sampled fish were separated into the following size categories: <35 mm FL, 35-74 mm FL, 75-149 mm FL and $\geq$150 mm FL, and counted by disposition category (dead or alive). Sub-sampling occurred primarily with screw trap catches, as the fyke net rarely caught enough fish to necessitate sub-sampling.

Rotary screw trap operation

In both study years, 8 ft diameter rotary screw traps were used for sampling. In 1997, an E.G. Solutions trap with a perforated plate cone (3/16 inch diameter) was used. The 1998 trap design employed a hardware cloth cone of 1/4 inch mesh. Both traps were mounted on pontoons, which were anchored to the headworks and the side of the canal approximately 120 ft (36.6 m) downstream of the A-canal headworks. A catwalk across the canal provided access to the trap. Captured fish were held in the live-box attached to the end of the cone. Both screw traps were designed primarily to collect outmigrating salmonids of > 35 mm FL. A general schematic of a rotary screw trap is presented in Figure 2.

During 1997 sampling, the screw trap was checked three times daily, once during each of the following three diel periods: 00:00 to 08:00, 08:00 to 16:00, and 16:00 to 00:00. A minimum of five hours was allowed to pass between each clearing of the trap. In 1998 the screw trap was typically checked twice daily, once in the early morning and again in the evening. In addition, from mid-June through early September 1998, on one day each week, sampling was conducted every six hours, at or near 06:00, 12:00, 18:00, and 24:00. This frequent sampling provided more specific information on the timing of fish movement into the canal.

At each check-time, debris and fish were removed from the live-box and separated into buckets. In 1998, debris was categorized as: Tules (bulrush - *Scirpus* sp. and cattail - *Typha* sp. remains), woody material, leaves, grasses, and aquatic macrophytes (e.g., stringy pond weeds - *Potamogeton* sp.), and the volume noted. At each check time, water velocities at the trap were obtained using a General Oceanics, Inc. (GO) velocity meter with a standard rotor (Model #2030R). The GO meter was deployed to obtain velocity data for water moving through the cone, which was in turn used to calculate the water volume fished for each screw trap set. The meter was weighted with a 5-lb lead weight and deployed from the front center of the south pontoon at 1.5 ft depth. The 1998 GO meter was calibrated prior to installation and found to be accurate to within ±2%.

Following sample collection and analysis, the revolutions per minute (rpm) of the screw trap cone were counted and recorded to evaluate trap efficiency (1998 only). According to Service Klamath River juvenile (salmonid) trapping protocols, optimum trap efficiency for the 1998 screw trap was at 20-25 rpm.

Fyke Net Operation

Similar fyke nets were employed in 1997 and 1998. In 1997, the fyke net mesh size was 2.5 inch (64 mm stretch measure). In 1998, the mesh size was reduced to 2.0 inch (51 mm stretch measure). Both nets were 6 ft wide by 10 ft tall, and 30 ft long (1.8 m x 3.0 m x 9.1 m), and sampled slightly less than one-third of the canal flow. The fyke net was mounted on a metal frame which was raised and lowered, using a cable and pulley system, between two vertical beams on the canal floor. A diagram of the A-canal fyke net and structure is presented in Figure 3.

Fyke net sampling was intended to catch large juvenile and adult fish (>200 mm or 8 inch FL), however smaller fish were sometimes trapped in the net when debris was present. This sampling was generally lethal, though live fish were occasionally removed at check-time.

During both sample years, the fyke net was checked twice daily, between 06:00-08:00, and between 18:00-20:00. At check-time, the net’s mouth was raised out of the water and the cod-end was pulled to shore. Fish and debris were removed from the cod-end and the net was again deployed. At canal flows of <550 ft^3/s the net could not be fully submerged. At these lower flows, the net was lowered to the canal floor and the submerged depth was recorded for use in sample volume calculations.

Since the fyke net traversed all or most of the water column and experienced different velocities based on depth, an average fyke net velocity was calculated daily based on canal flow data and the associated cross-sectional wetted perimeter of the canal. Daily canal flow rate and the mathematical conversion from flow rate to mid-water column velocity were provided by the KID. Calculated daily velocities, based on KID mean daily canal flows, were multiplied by the cross-sectional profile of the submerged fyke net to subsequently determine sampled water volumes.

Fish handling

Sample fish were transported to our field station, an on-site storage shed, for data collection. Once there, sample fish were typically transferred to 25-gallon holding containers where aerators could be added to holding waters. To minimize stress, a slime coat promoter (Stress Guard™) was often added to the water.

The field station was also equipped with a continuous-flow system for two 200-gallon Rubbermaid® troughs. An electric pump continuously filled the troughs, which were fitted with screened, perforated PVC standpipes that allowed for water level control and drainage. This system was used to maintain fish for efficiency testing and for recovery of large suckers (generally >200 mm FL).

Due to difficulties in determining the species of small suckers using morphological characteristics, species classifications were only made on larger individuals (generally >100 mm FL), or when identifying features were clear. Consequently, catostomids were listed either by species name - Lost River (LR), shortnose (SN), Klamath largescale (*Catostomus snyderi*; KL), or as sucker unknown (SU). Similarly, small Klamath Lake sculpins (*Cottus princeps*) and the less frequently encountered slender sculpin (*C. tenuis*) were often combined into the category - sculpin unknown (SC). Pumpkinseed sunfish (*Lepomis gibbosus*) and bluegills (*L. macrochirus*) were combined into the category of *Lepomis* unknown (LP).

Following measurement, all live non-catostomids were released into the A-canal below the fyke net. Dead fish were frozen and donated to local wildlife rehabilitation centers for animal feed. Suckers and trout were primarily released in Upper Klamath Lake at the Moore Park Marina approximately one mile west of the A-canal intake. However, to enhance their survival during 1998 high temperature and high sucker catch periods (>200 suckers per day) suckers were released at Barkley Springs in Hagelstein Park, 10 miles north of Klamath Falls.

During both years, a representative sub-sample of dead juvenile suckers (<150 mm FL) was preserved in alcohol. All large sucker moralities (>200 mm FL) were labeled and frozen. Alcohol preserved suckers were sent to OSU biologists for species identification and research purposes. Frozen suckers were delivered to Reclamation for species verification and pit-tag scanning.

Efficiency Testing

Efficiency tests were performed to simulate the entrainment of Upper Klamath Lake fish into the A-canal by releasing a known quantity of fish and determining their recapture rates. Efficiency test data were expected to provide a correction factor with which we could determine total A-canal fish entrainment, however, our results (covered in Results and Discussion) were inconsistent and could not be used for this purpose. Instead, entrainment indices were calculated using volumetric expansions which accounted for time periods and water volumes which were not sampled.

Screw trap efficiency tests were generally run weekly, when sufficient fish were available. Test fish were collected primarily from A-canal and Link River sampling operations and maintained in the field station holding tanks. Typically 75-200 fish, which ranged from 60 to 225 mm FL, were used for testing. Species used were blue chub, tui chub, and yellow perch (*Perca flavescens*). The efficiency of the fyke net was not tested because quantities of test fish >200 mm FL were ordinarily unavailable. However, fyke net catches were examined for clipped fins and screw trap efficiency fish were occasionally sampled.

For each test, fish were measured and the right or left pelvic fin was slightly clipped. The fish were placed in paper bags filled with water 25-40 at a time, and lowered on a weighted cord just behind the canal headworks. When the bag of fish was caught by the headgate inflow, the attaching rope was tugged to break the sack and release the fish. For the remainder of the week, all fish in the appropriate size range were examined for clipped fins and recaptures were noted.

Data analysis

The following sections present the methodology used to determine sample velocities for the screw trap and the fyke net. These velocities were subsequently used to calculate the volume and catch per unit effort (CPUE) for each sample.

Screw trap calculations: To determine the compatibility of 1997 and 1998 screw trap velocity estimates (given that different GO meters were used in each year), logarithmic relationships were developed between measured sample velocities and canal flow rate (ft^3/s from KID) for both years. Specifically, the Log_{10} of all daily 1997 and 1998 screw trap velocities (ft/s) were graphed against the Log_{10} of average daily canal flow rates. The equation of the line for each year was then calculated, and the yearly correlation coefficient (R^2) computed (Figure 4; A and B).

Since there were no changes in the physical configuration of the A-canal over this period, the relationship between screw trap velocity and canal flow should have been uniform, with similar R^2 values. However, this was not the case. Instead, the correlation between screw trap velocity and canal flow rate was stronger in 1998 ($R^2 = 0.87$) than in 1997 ($R^2 = 0.5$). To maximize accuracy and to permit comparisons between years (as velocity data is used to calculate catch per volume sampled), the antilog of the 1998 equation was used to calculate all screw trap sample velocities, based on canal flows, in both years (i.e., Screw trap velocity (ft/s) = 0.0212*(canal $ft^3/s)^{0.7281}$.

Fyke net calculations: As the fyke net traversed the water column (as opposed to sampling surface or bottom waters), an average canal velocity estimate was considered more appropriate for sample volume calculations than the surface estimate used with the screw trap. Consequently, data provided by the KID on the cross-sectional wetted perimeter of the canal at different flows were employed using the relationship: Flow (ft^3/s) / Area (ft^2) = Velocity (ft/s). From this, the following equation was derived: Average A-canal water column velocity (ft/s) = 0.0607*(canal flow rate in $ft^3/s)^{0.6154}$. Calculated fyke net and screw trap velocities vs. canal flow rate are presented in Figure 4C. The average estimated fyke net velocity was always greater than the velocity of the screw trap sampled water because the screw trap filtered waters where velocities were typically slowed by surface drag.

CPUE calculations: CPUE values for all fishing methods were calculated as the number of fish caught per 100 acre-ft of water sampled (The same index was used to present CPUE estimates from the Link River power-canals; Gutermuth et al. 1999). To calculate fyke net CPUE values, two data adjustments were performed.

1) At canal flows <550 ft^3/s, some portion of the fyke net was above water. Consequently, the recorded submerged depth of the fyke net was needed to determine the sampled water volume. At flows >550 ft^3/s, the entire 10 ft vertical portion of the fyke net remained submerged. However, at such high flows, the force of the water prohibited lowering the net much below the water surface.
2) Because the screw trap was positioned immediately upstream of the fyke net, water which flowed through it was already sampled and needed to be removed from that filtered by the fyke net. Since the screw trap was wider (8 ft) than the fyke net (6 ft), it was calculated that only 20 ft^2, of the screw trap's 23 ft^2 fishable surface area, fished water before it passed through the fyke net. Therefore, 20 ft^2 were subtracted from the fyke net surface area used in sample volume calculations.

The following formulas were necessary to calculate CPUE values on a standard 24-hour basis, for day-time, night-time, and sucker catches:

1) Surface area sampled for each method:
   Screw trap surface area (submerged radius = 3.8 ft) = (pi x 3.8^2)/2 = 22.7 ft^2
   Fyke net surface area = (fyke net submerged depth x 6 ft width) – area of screw trap blocking the fyke net (20 ft^2) = up to 40 ft^2.
2) Sample flow rate based on velocity and surface area:
   Sample flow rate in ft^3/s = sample velocity (ft/s) * sample method surface area (ft^2).
3) Sample volume based on sample flow rate and time fished.
   Convert sample volume to 100 acre ft (1 acre ft = 43,560 ft^3):
   Sample volume (100 acre ft) = ((sample flow rate in ft^3/s) * (seconds fished))/4,356,000.
4) CPUE (fish/100 acre ft.) based on catch and sample volume:
   CPUE of species X = total catch species X /sample volume (100 acre ft.).

Entrainment index calculations

Estimates of total fish entrainment into the A-canal (entrainment indices) were calculated using volumetric expansions which accounted for time periods and water volumes which were not sampled. These volumetric expansions assumed an equal distribution of fishes throughout the A-canal inflow and relied on the accuracy of the canal flow data provided by the KID (±5%; Flows were typically adjusted at 06:30 each morning - Dave Solem, KID manager, pers. comm.), the GO velocity meter (±2%), and the consistent sampling efficiency of the screw trap.

Daily volumetric expansion of data was standardized to cover a 24 hr period based on the percent of the A-canal water volume and time sampled each period. Seven daily totals were then summed to present entrainment indices on a weekly basis. The proportion of the weekly entrainment index, which was made up by an individual species or size category, was considered to be the same as the percent of the weekly total catch which this species (size category) represented.

When only part of a day was sampled, a 24 hour catch was estimated by multiplying the number of hours fished (hr) by the week's mean hourly fish catch for the appropriate day or night time period (fish/hr). This quantity was added to the fish handled in the day to estimate the 24 hr catch. When no sampling occurred, daily entrainment indices were calculated by averaging the estimates from the day prior and following the missing interval.

The following equations provide details for calculating the "24 hr standardized A-canal entrainment index" under each of four encountered scenarios:

Total index (general case) =	(total catch) /(% canal sampled) /(% day sampled).
Missing night sample =	(day catch + **(**(24 - day hours fished) * (average weekly fish/hr for night samples)**)**) / % of the canal sampled / (% day sampled).
Missing day sample =	(night catch + **(**(24 - night hours fished) * (average weekly fish/hr for day samples)**)**) / % of the canal sampled / (% day sampled).
Missing full 24 hr sample =	(prior 24 hr index + following 24 hr index) / 2.

RESULTS AND DISCUSSION

Sampling effort

In 1997, screw trap sampling was initiated on May 12 and fyke net collections on June 30. During that year, 14,740 acre-feet of water were fished by the screw trap during 3,191 hours of sampling, and 23,920 acre-feet were fished by the fyke net in 2,162 hours of sampling. In 1998, fishing with both gears commenced on April 22. The screw trap fished 11,250 acre-feet in 2,615 sample hours, and the fyke net fished 23,310 acre-feet in 2,395 hours of sampling. The volume of canal water from which we have made entrainment estimates increased from 221,800 acre-ft in 1997 to 232,700 acre-ft in 1998.

After the start of sampling, there was very little down-time during either season. In 1997, the screw trap live-box was under repair from May 31 to June 11. In 1998, the live-box was serviced from July 13-14, and the fyke net was out for frame structure renovation from July 27 to 30. Table 2 presents a summary of the two-year sampling effort and weekly catch totals for all species ($\geq$35 mm FL).

Abundance and catch composition

All species: The 1997 combined total catch (screw trap plus fyke net) was 32,364 fish. In 1998 the total catch was 57,267 fish. The screw trap captured substantially more fish (56,394) in 1998 than in 1997 (30,136 fish). Despite a ½ inch reduction in the fyke net mesh size from 1997 to 1998, the opposite was true for this gear. A total of 873 fish were caught in the fyke net during 1998 and 2,228 were collected in 1997. A weekly summary of screw trap catches, by species, is presented in Table 3. A weekly summary of fyke net catches is displayed in Table 4.

Suckers: The total catch of catostomids for both methods combined was 3,555 in 1997 [3,239 (11% of all captured species) by the screw trap and 316 (14% of all captured species) by the fyke net]. In 1998, the total sucker catch was 9,879 [9,799 (17% of all captured species) caught by the screw trap and 80 (9% of all captured species) by the fyke net]. The sucker catch was substantially higher in 1998, largely due to an increase in age-0 collections. For both years and methods combined, the majority of suckers were caught in August (76% in 1997 and 68% in 1998), however, numerous suckers were collected in September 1998 (25%).

In 1997, suckers were sampled during most of the period that the screw trap fished, but in 1998 their collection was almost entirely age-0 fish which moved through in the late summer. During 1997 suckers comprised up to 26% of the screw trap catch in early August, yet in 1998 they frequently made up 30-50% of the catch during the "movement" period (Table 3). In the 1997 fyke net catches, suckers comprised up to 48% of the weekly sample and were usually over 20% of the collected fish (Table 4). In 1998 suckers comprised a maximum of 28% of the fyke net catch in September and averaged only about 13% during the highest July-September catch period.

CPUE: Screw Trap: During both years of screw trap sampling, the catch of all species remained relatively low through mid-July. By late-July 1997, sucker catches increased rapidly and peaked during the week of August 4^{th}. Sucker catches then declined gradually for the remainder of the season. The 1997 catch of all species increased in late July and September, but remained high through the sampling season. In 1998, sucker screw trap catches also increased rapidly in late-July, but did not peak until late August, and remained high through late-September. The 1998 catch of all species increased during the same period but multiple peaks in catch occurred through late September when catches diminished. Screw trap trends are depicted in Figure 5 which presents sucker and all species weekly CPUE values for 1997 and 1998.

CPUE: Fyke-net: As with screw trap catches, fyke net catches increased in both years during late-July and August. However, 1997 CPUE values were far greater than in 1998. In 1997 sucker and all species CPUE values increased rapidly, peaked, and then slowly decreased. Peak catches in this year were made during the week of August 18, concurrent with a fish kill in Upper Klamath Lake. During this period, many of the sampled fish were either dead or dying prior to collection. In 1998, both sucker and all species CPUE values increased in the same time period, late-July through late-September, but the increases were not nearly so pronounced. Weekly fyke net CPUE values for suckers and all species are presented by year in Figure 5.

Species composition and timing: In all sampling prior to July, blue chubs dominated the catch (50-90%) for both methods in both years. Tui chubs (*Gila bicolor*) were also common (>10%) during this period in 1997 and fathead minnows (*Pimephales promelas*) were in 1998. By mid-July, the catches and the diversity of sampled species increased (Table 3; Figure 6).

In 1997, the native fishes, (blue chubs, tui chubs, and all suckers) made up 87% of the screw trap catch; in 1998, they comprised only 52%. In 1998 the sampled fish community was generally more diverse with more abundant fish species of both native (e.g., sculpin species) and non-native (e.g., yellow perch and fathead minnows) origin (Table 3; Figure 6). Figures 6 and 7 display the predominant species (percent composition) sampled in the screw trap and fyke net, respectively. Appendix Figure A1 displays the number of fish sampled weekly in the screw trap, by species and year.

The species composition from the 1997 screw trap sampling was as follows: blue chubs (54%), tui chubs (22%), all suckers combined (Catostomidae; 11%), fathead minnows (4%), all sculpin combined (Cottidae; 8%), and yellow perch (1%). The species composition sampled in 1998 was: blue chubs (25%), tui chubs (10%), all suckers combined (17%), fathead minnows (32%), all sculpin combined (12%), and yellow perch (4%). In addition, from a representative sample of small (generally <100 mm FL) 1998 A-canal unidentified suckers, which was sent to OSU for classification using x-ray analysis, the following species breakdown was reported: 74 shortnose (52%), 57 Lost River (40%), 1 Klamath largescale (1%), and 9 unidentifiable (6%) suckers. This is in slight contrast to the identification of similarly sized Catostomids collected on the Link River canals (eastside and westside). From these canals, shortnose suckers comprised over 60% of the samples and Lost River suckers only about 30%. Klamath largescale suckers consistently were found to make up only about 1% of the suckers sampled at all sites. This make-up of small sucker species is also quite different than that reported by Peck (1999a) in his identification of large suckers (>160 mm FL) during post-irrigation season canal fish salvage efforts. Peck (1999a) documented the following sucker species composition from his 1998 A-canal salvage work: 159 Klamath largescale (60%), 96 shortnose (36%), and 10 Lost River suckers (4%).

Rainbow trout were occasionally caught in the screw trap (27 total for both years) and not at all in the fyke net. Catches occurred primarily during May and June while lake water temperatures were still relatively cool. Other infrequently collected species included lampreys (*Lampetra* sp.), speckled dace (*Rhinichthys osculus*), pumpkinseed or blue gill sunfish (*Lepomis* sp.), and brown bullhead (*Ameiurus nebulosus*).

We believe that an increase in August-September 1997 entrainment rates of large fish (>150 mm FL) resulted primarily as stressed and debilitated fish moved from severely degraded water quality conditions in Upper Klamath Lake during a fish kill. Numerous age-0 fish, which were in relatively good condition, were also collected at that time. These fish were likely stressed by poor water conditions, but may also have been moving in response to other stimuli (e.g., competitive interactions, attraction to flows, temperature, etc.). Consequently, the increased late-summer catches may, when combined with similar 1998 patterns, suggest an annual movement pattern. In 1998 peaks in fish collection corresponded to runs of age-0 fish, where one or two species dominated the catch for several days to weeks then declined. For example: The weeks of July 13th and 20th were comprised of 53% and 43% yellow perch, respectively. The weeks of August 3rd and 10th were 33% and 27% sculpins (Klamath Lake and some small component of slender sculpin, combined). For the weeks of August 10th through September 7th, catostomids comprised >20% of the catch and up to 50% (Figure 6).

<u>Size/age class distribution</u>

<u>Suckers</u>: According to the criteria established by the Service in their biological opinion on PacifiCorp and New Earth operations (USFWS 1996), future entrainment reduction measures must exclude suckers >75 mm FL. Consequently, information reported in this document has divided the sampled fish lengths into size categories of: <75mm, 75-150 mm, and >150 mm FL. A breakdown of the screw trap catches into these categories, which approximate sucker age classes (age-0, age-1, and age-2+) for most of the year, is presented in Figure 8. A comparison of 1997 and 1998 sucker size distribution clearly indicates the greater proportion of sampled age-1 and older suckers in 1997 and the proportional increase in 1998 of entrained age-0 year suckers. The similarity in collection timing between years suggests that a portion of the age-0 sucker year class may leave the lake in late summer, but additional years of data would be needed to substantiate this phenomenon.

After first collections in June, age-0 suckers were relatively abundant in the screw trap by July of both years. By late July, and the beginning of the high sucker catch period (July 15-30) age-0 suckers averaged 45 mm FL in 1997 (range 27-88 mm) and 37 mm FL in 1998 (range 19-80 mm; Figure 9). The higher total 1998 age-0 sucker collections suggest that 1998 was a stronger year class than 1997. Likewise, collections of suckers during Reclamation's canal salvage (Green 1998), OSU sampling (Simon et al. 1998), and New Earth/Cell Tech canal research (Gutermuth et al. 1998) all corroborate that 1997 was a lower reproductive year for suckers as compared to 1998. However, it is possible that minimal 1998 age-1+ sucker collections simply indicate that age-1+ suckers are less frequently near the lake outfalls than age-0 suckers.

During 1997 screw trap sampling, age-1 and older suckers were often collected. In 1997, 29% of measured suckers (3,128) were >100 mm FL while in 1998 only 1% of the measured suckers (100) were of this size. Similarly, larger suckers (>200 mm FL) were sampled in the fyke net more frequently in 1997 than in 1998. The 1997 fyke netted suckers ranged from 56 to 522 mm FL and averaged 300 mm FL, which corresponds to an age 2-4 shortnose or Lost River sucker (USGS 1996; Figure 10). In 1997, only 1% (4) of the fyke net collected suckers were <100 mm FL while in 1998, 36% (29) of the fyke netted suckers were of this size. This circumstance may be at least partially attributable to the smaller mesh net used in 1998. Outside of the peak collection period around the August 1997 fish kill, there was little discernible periodicity in large fish movement into the A-canal. It is possible that large suckers succumbed to poor water quality in 1997 in such numbers that the population was reduced and fewer numbers were available for sampling in 1998. However, since Reclamation radio tagging results indicate that adult suckers (>300 mm FL) primarily inhabit the northern lake during summer (B. Peck 1999b), large suckers in 1998 may not have migrated from the northern portion of the lake because of more favorable water quality conditions there than in 1997. Monthly length frequency histograms for 1997 and 1998 screw trap and fyke net sucker catches are presented in Figures 9 and 10, respectively.

Blue chubs: Monthly length frequency histograms for blue chubs collected in the screw trap were developed to compare the size distribution of this species with the collected suckers. As with suckers, more "large" blue chubs were collected in 1997, probably due to water quality problems in that year, than in 1998. However, unlike the sampled 1998 suckers, multiple age classes of blue chubs (>75 mm FL), were still common in that year. This suggests that blue chubs were not so detrimentally affected by 1997 poor water quality periods as suckers. This conclusion corroborates 1997 OSU fieldwork where a healthy population structure of blue chubs, with representation of most age classes up to age-17, was found (Simon et al. 1998). Blue chub length frequency data is presented in Appendix Figure A2.

Movement patterns and environmental correlations

Diel fish movement: During 1997 screw trap sampling, the trap was generally checked prior to 08:00, at or near 14:00, and again prior to sunset. Therefore, 1997 morning catches included fish collected during both dawn and dusk entrainment periods. In 1998, one day per week was sampled every six hours at or near 06:00, 12:00, 18:00 and 24:00, to determine if intra-day periods of increased fish movement existed.

In both years, early season day and night screw trap CPUE values were similar, though night sampling rates were generally higher (Figure 11). In August of 1997 day-time rates increased and night-time catch rates increased substantially, however, night-time CPUE values generally decreased by mid-September. It is possible that increased August 1997 night time movement represented a combination of relatively healthy fish engaged in late-summer movement and stressed fish which were exhibiting diel migratory behavior. The expanded late-summer day-time movement was longer lived and probably resulted as fish became incapacitated by poor water quality (and resulting stressors - e.g., disease, fungus, parasites, etc.) and floated into the trap.

During 1998 sampling, day-time CPUE values remained low throughout the season, and night-time values were markedly higher than in 1997 (Figure 11). Data from 1998 six-hour sampling indicate that screw trap collected fish moved primarily during both evening (18:00-24:00) and morning (00:00-06:00) hours, especially during the high catch August-September period (Figure 11). These crepuscular movement patterns are similar to those reported by the U.S. Geological Survey for adult suckers during their spring 1997 sampling of the Williamson River spawning run (USGS 1997).

Lake level and discharge: During the summer of 1998, Reclamation conducted velocity profiling in the southern portion of Upper Klamath Lake during both high (4143.1 ft) and medium (4140.2 ft) lake level conditions. Resulting measurements, which were made with a Doppler acoustic velocity meter, indicated that southern lake velocities were quite variable, in strength and direction, depending on the lake level and the magnitude of out-flows. During high lake elevations, medium-low A-canal withdrawal, and a relatively large combined Link River discharge (3,745 ft^3/s – total from Link River spill, eastside and westside power canals), the strongest velocity vectors swept down the Link River. However, later in the year, at a lower lake elevation, low Link River total discharge (1,060 ft^3/s), and medium A-canal flow, the strongest velocity vectors oriented toward the A-canal. This second condition, depicted in Figure 12, annually corresponds to the August-September period when high entrainment was evident in 1997 and 1998. Though healthy juvenile suckers could behaviorally avoid or swim against these velocities (2-3 ft/s), they are relatively high compared to the 1.08 ft/s critical swimming speed, for juvenile Lost River and shortnose suckers, determined by DeLonay and Little (1997). If these fish were performing some sort of density dependent or passive dispersal, they might easily follow such a velocity pattern into the A-canal.

To determine if a relationship between catch rates and A-canal flow rates, Upper Klamath Lake elevations, and total lake outflow exists, all fish and sucker weekly mean screw trap CPUE values were graphed together with weekly averages for A-canal flows, lake elevation, and south lake outflow (i.e., A-canal + Link River and powerhouses; Figure 13). Similar to work done on the Link River power canals (Gutermuth et al. 1999), these graphs did not depict any strong correlation between CPUE values and these parameters. However, all of the highest CPUE values were measured during periods when lake levels were relatively low, which is auto-correlated with late season. After sucker CPUE values reached their peaks, these values tended to decrease along with diminishing canal flows at the irrigation season's end, especially in 1997 (Figure 13B). For all fish, CPUE values were highest, in both years, after maximum A-canal flows had passed. The highest sucker CPUE values were recorded during high A-canal flows (800 ft^3/s in 1997 and 960 ft^3/s in 1998), but also continued during lower flow periods ($\leq$611 ft^3/s in 1998). Overall, the catches often grew with increased A-canal flow, because we filtered relatively more water during a similar sample duration, however the CPUE did not increase. Since there is not a tight correlation between flows and CPUE values, it is doubtful that fish were uniformly distributed in the waters of southern Upper Klamath Lake.

The highest sucker CPUE values occurred at Upper Klamath Lake elevations of $\leq$4141 ft and the highest CPUE values for all fish were measured at lake levels $\leq$4141.7 ft. In August and September, when these lake levels occur, velocities leading to the A-canal headworks are typically high and may be attractive to fish.

The higher entrainment rates of age-0 suckers in the A-canal during late summer of 1998, as contrasted to 1997, corresponded to that year's higher late-summer A-canal and total south lake outflows (Figure 13B). These data may suggest that if passive dispersal of age-0 suckers occurs, higher lake outflows in late summer (i.e., inclusive of Link River and powerhouses) would expose more suckers to the vicinity of the A-canal headworks. For comparison, data are required from low water years when diminished springtime river inflows might result in a decreased distribution of larval and early juvenile suckers through Upper Klamath Lake.

Water quality: The summer of 1997 began very warm and Upper Klamath Lake had an early bloom of blue-green algae. Algal photosynthesis quickly elevated the lake's early season pH and caused dissolved oxygen levels to fluctuate daily. During calm weather periods, the high pH allowed toxic levels of un-ionized ammonia to build (Kann unpublished data as cited by Simon et al. 1998). Then in August 1997, poor water quality conditions and an outbreak of Columnaris disease caused an extensive fish kill for the third year in a row (Buettner 1997; pers. obs.). There is no doubt that poor water quality conditions increased the 1997 fish collections, however, there may have been other movement patterns that were masked by this year's influx of stressed and dying fish. Water quality conditions improved in 1998, but due to the size of Upper Klamath Lake, it is difficult to monitor and characterize all the lake-wide parameters which could have influenced fish community movements. In this section we review water chemistry data, with reference to known stressful conditions and our own records of sampled fish condition (e.g., Disposition - alive or dead, and physical abnormalities), in an attempt to explain fish activity. Specifically, we examined continuously recorded (hourly readings) water quality data from the headworks of the A-canal (Reclamation unpublished data) and instantaneous water quality readings from Cell Tech, in order to assess the effects of lake temperature, specific conductivity, ammonia, pH, and dissolved oxygen conditions on entrainment rates (Figures 14 and 15). Sucker tolerance limits to some of these water quality parameters are summarized in Table 5.

Stressful water temperatures of >29.4ºC (Bellerud and Saiki 1995) were not recorded at the headworks during either sampling year and specific conductivity readings were as expected for the low ionic strength waters of Upper Klamath Lake. Conductivity readings remained in the range of 104 ± 9.9 microsiemens/cm (µS/cm) in 1997 and 110 ± 6.4 µS/cm in 1998 (Reclamation unpublished data).

Though ammonia data for the headworks were not available, unusually high un-ionized ammonia concentrations, which would have been stressful or lethal to larval/juvenile suckers, were frequently measured during summer 1997 lake sampling. In July 1997, twenty-eight water samples had a mean un-ionized ammonia concentration of 1.01 mg/l and 39% (11) were greater than 1.00 mg/l (Kann 1997 unpublished data as reported by Simon et al. 1998). Such high un-ionized ammonia levels prompted Simon et al. (1998) to hypothesize that substantial mortality of age-0 suckers may have resulted in 1997. In contrast, during July 1998 sampling, average lake un-ionized ammonia concentrations averaged only 0.33 mg/l (14 samples; Cell Tech: R&D unpublished data). August samples averaged 0.18 mg/l (7 samples) and September samples averaged 0.12 mg/l (28 samples; Cell Tech: R&D unpublished data).

By early June 1997, pH at the headworks rose to >9.5, a level which causes shortnose suckers to loose their equilibrium in laboratory tests (Falter and Cech 1991), and remained high through late July. Concurrently, high and daily fluctuating dissolved oxygen concentrations (DO) added to conditions considered as impairing for fish (Stewart et al. 1967). At the start of August, a large-scale algae die-off occurred and daily average DO dropped to levels < 4.0 ppm, considered stressful for warm-water fishes (Davis 1975). The screw trap sucker CPUE values peaked shortly thereafter in mid-August 1997, one and two weeks after the algae die-off. Fyke net sucker and all fish CPUE values were also high through this period (Figures 14 and 15). Given the lengthy early summer period of high pH, the subsequent extended duration of low oxygen conditions (approximately 3 weeks of fluctuating DO near and <4.0 ppm), and high water temperatures, we expect that many of the sampled fish were incapacitated by or migrating from poor lake conditions. At that time, screw trap catches included predominantly age-0 suckers, though age-1 and older suckers were also collected in large numbers (Figure 8).

During the highest catches in August 1997, an extensive fish kill occurred in Upper Klamath Lake (Buettner 1997, pers. obs.). At that time, the collected suckers (Figure 16) and other fish, were dead or in poor condition. While it is clear that poor 1997 water quality debilitated the fish community and increased the catches, we expect that the effect was most detrimental to larger fish because these are frequently the first to succumb under low oxygen and poor water quality conditions (Herman and Meyer 1990). Of the sampled suckers, the largest fish appeared during the poorest water quality condition (e.g., during the week of August 11-18, 1997, 32% of the dead suckers were ≥150 mm FL and only 16% of the live suckers were this size). Small fish, which were probably also escaping poor lake conditions, were still in overall better condition and more capable of directed movement.

Upper Klamath Lake water quality was better in 1998 and no fish kills were reported. During that year, the pH fluctuated above 9.5 for only one mid-July week. On August 8th, however, a six-day period of low DO (daily lows <4.0 ppm) began. The screw trap CPUE values peaked six weeks following the high pH, and two weeks after the low DO period. The fyke net CPUE values increased slightly in mid-July but remained relatively low through high pH and low DO conditions (Figures 14 and 15).

In 1997, many collected Upper Klamath Lake fish were dying from stressful conditions and resultant breakouts of Columnaris disease. In 1998, some fish may have been swimming to evade poor conditions (e.g., low DO, Figure 14), but some of the age-0 fish may have moved for other reasons. In 1998, fish were in better condition than in 1997 (Figure 16) and appeared to move through in pulses (Figure 6). In 1997, the catch of dying or dead suckers (51%; Figure 16A) was highest during peak sucker collections. The late-summer, day-time CPUE values for all fish were also very high, and after long-term exposure to chronically stressful conditions, the 1997 day-time CPUE values were sometimes greater than night-time values (Figure 15). Very low 1998 day-time CPUE values, and the great difference between day and night values in that year, suggest that 1998 fish were performing a movement pattern different than 1997 (Figure 15). In 1998, peak collections of dead suckers occurred before the largest catches [during the weeks of July 20 (67% dead) and August 3 (52% dead); Figure 16]. Suckers caught during peak 1998 periods were not floating through the system as they were in 1997. Though most fish collected in 1998 were relatively active, the effects of high 1998 temperatures and some degree of poor water quality did impact the health of collected fishes. The percentage of 1998 collected suckers which received physical condition remarks (e.g., parasites - *Lernaea* sp. or trematodes, wounds, fungus, shortened operculum, etc.) is included in Figure 16C.

Though stressful conditions did exist in 1998, they were less severe and shorter in duration than in 1997. In 1997 water quality at the headworks was first extremely poor (with some hourly DO readings of <4.0 ppm) on July 29. On July 30, 1997, DO readings plummeted to 2.4 ppm and the unit stopped recording. When the multi-probe was replaced on August 7th, hourly readings were still occasionally <4.0 ppm. A total of four days then (August 9-12) averaged less than 4.0 ppm (24 hr mean) and included readings below 3.0 ppm. Overall, we expect that there were 17 consecutive days of very poor water quality (July 29-August 15) at the headworks in 1997 compared to only six consecutive days (August 11-16) in 1998.

Compared to the timing of maximum 1997 catches, the 1998 sucker collections approximated a more protracted normal distribution (Figures 5, 14, and 16). The 1997 catches moved from low sucker CPUE values (<20 su/100 acre ft), to high values (100 su/100 acre ft) within a week whereas CPUE values in 1998 increased more gradually. Furthermore, a higher rate of sucker entrainment was evident in 1998 (e.g., >500 su/100 acre ft at the peak), than in 1997 (100 su/100 acre ft). Though the specific reasons for movement are unclear, species composition trends for all fish in 1998 also showed definite peaks, which we interpret as movement of individual species as they were cued to disperse by species-specific environmental or density-dependent cues (Figure 6). In 1997, there appears to have been one extended migration of all species, during day and night periods, which was probably greatly influenced by poor water quality conditions. Based on the magnitude and comparable timing of movement between years, and the relative health of the sampled fish, we speculate that some age-0 suckers probably leave the lake annually as they did in 1997 and 1998 regardless of water conditions.

The mechanisms affecting sucker dispersal from Upper Klamath Lake are obviously varied, complex, and interrelated. Our limited data collected in 1997 and 1998 suggest that water quality and total outflow are among the most apparent parameters influencing dispersal although there are probably other behavioral mechanisms which are not fully understood.

<u>Entrainment indices for total A-canal sucker entrainment</u>

<u>Method determination</u>: When rotary screw traps are employed to determine the timing of salmonid out-migration, total fish passage indices are usually generated with the use of trap efficiency data obtained from efficiency tests. In each efficiency test, a known number of marked fish is released upstream of the traps and the percentage of these which are recaptured noted. If the fish are uniformly distributed with flow at the trapping site and gear avoidance does not occur, the trap efficiency should be proportional to the discharge volume and is calculated as the number of fish recaptured divided by the number released. A

total salmonid outmigrant index is then estimated by dividing the total catch by the appropriate efficiency value (for the same volume and environmental conditions) at the trap.

To estimate the efficiency of the trap in the A-canal, 28 efficiency test releases were completed in 1998. Of these, 19 used live fish and 9 employed dead fish. The results of these mark-recapture tests indicated that there was no consistent relationship between estimated trap efficiency and canal flow (Figure 17). Consequently, total weekly canal entrainment indices were alternatively estimated based on volumetric expansion of the sampled screw trap volume to the total canal amount. These indices assumed a uniform distribution of fish throughout the canal water column and rely on the accuracy of KID flow data (+/-5%) and the GO velocity meter (+/-2%). These calculations, which are explained in the Materials and Methods section, also depend on the consistent efficiency of the screw trap.

Despite their inadequacy for extrapolation, the mark-recapture efficiency test results are revealing. When compared to the percent of the canal volume sampled, the proportion of fish recaptured was consistently less than the proportion of flow sampled at lower canal flow levels (<600 ft^3/s; Figure 17). Flows higher than this level were also necessary to achieve the Service recommended screw trap rotation rate of 25-30 rpm. Though not quantified here, a correction for reduced trap efficiency at low canal flows (<600 ft^3/s) would increase entrainment indices during early and late season sampling when canal flows were at or near this level (Table 2).

<u>Volumetric expansion</u>: The following yearly indices combine screw trap and fyke net results. The total 1997 A-canal entrainment index was estimated at 465,536 fish of all species and included 46,708 suckers. The 1998 entrainment index was 1,239,801 total fish and included 246,524 suckers. The larger 1998 entrainment index is primarily due to other variables previously discussed and the more numerous age-0 fish sampled in that year which probably indicates a stronger year-class strength than in 1997. A weekly summary of entrainment indices for both gear types and all sampled fish is provided in Table 6. Weekly sucker entrainment indices are summarized in Table 7.

The only available data for comparison with this information is that from the annual salvage of the Klamath irrigation canals which is performed by Reclamation personnel in order to recover endangered fishes to Upper Klamath Lake. Peck (1999a) reported a larger number of suckers (2,717) in 1998 than in 1997 (2,383) and fewer large suckers (>240 mm FL) in 1998 (237) than in 1997 (378). While these trends agree with those found in this work, the difference in the number of annually collected suckers is not nearly so large as that estimated in this study. Though many more age-0 suckers passed the headworks in 1998 than in 1997, we expect that relatively few of these survived through summer anoxic conditions which frequently develop there, to be salvaged by Reclamation crews. In both study years, headworks DO fell to lethal levels of 3 or 4 ppm and canal DO was probably frequently 2 ppm less than these concentrations (Gutermuth et al. 1998). Consequently, extremely poor canal water quality conditions probably left few refuges for survival.

<u>Debris loading</u>

Debris loading at the screw trap was more dependent upon the season than on the canal flow rate. Debris loading rates were highest during the spring and late summer/fall. Tules (bulrush - *Scirpus* sp. and cattail - *Typha* sp. remains) were the predominant debris type recorded at the screw trap. Woody debris, especially in late May and mid-August, was the second most common debris encountered. Aquatic vegetation (e.g., stringy pond weeds - *Potamogeton* sp.) increased in abundance during late-September. In September and October, debris loading was a mixture of all five debris classes. Aside from several peaks which resulted from dock cleanings, and despite high flows, August debris loading was the lowest. Figure 18 presents a summary of 1998 screw trap debris composition (A), and daily debris loading (B), along with average daily canal flow rates.

Comparison of A-Canal to Link River Eastside and Westside canal entrainment

Due to the complex southern lake hydrologic environment in which these outfalls exist, screening of the A-canal will likely effect Link River entrainment. Consequently, it is important to understand the extent of entrainment at all Upper Klamath Lake outflows, as well as the timing, species, and sizes of fish that might be impacted, before entrainment reduction devices are for use at these sites. Presently Reclamation leads the Upper Klamath Lake entrainment reduction working group, whose charge it is to study Upper Klamath Lake entrainment and alternatives for its reduction, as well as to coordinate all efforts to this end.

Though the Link River studies employ fyke nets, which are not equivalent (between themselves or with the A-canal screw trap), in their ability to collect small (<75 mm FL) fish, some general trends in collected fish are comparable (Gutermuth et al. 1999). Similar to this work, in both Link River study years, collections of suckers and other fishes increased dramatically in the late-summer period and declined in the fall. During the 1997 fish kill year, a diverse assemblage of sucker age-classes were collected at all sites, but in 1998 age-0 suckers dominated the catch.

The two years of 1997 and 1998 are not representative of all water conditions that might affect fish migration patterns in Upper Klamath Lake. These were both wetter than average water years where the level of Upper Klamath Lake was maintained at a high level (>4140 ft). Though 1998 was better water quality at the headworks, we are not sure of what influences these fish to move.

SUMMARY

- All species catch: The 1997 combined total catch (screw trap plus fyke net) was 32,364 fish. In 1998 the total catch was 57,267 fish. The screw trap captured substantially more fish (56,394) in 1998 than in 1997 (30,136 fish). Despite a ½-inch reduction in the fyke net mesh size from 1997 to 1998, the opposite was true for this gear. A total of 873 fish were caught in the fyke net during 1998 and 2,228 were collected in 1997.

- Sucker catch: The total catch of catostomids for both sampling methods combined was 3,555 in 1997 [3,239 (11% of all captured species) by the screw trap and 316 (14% of all captured species) by the fyke net]. In 1998, the total sucker catch was 9,879 [9,799 (17% of all captured species) caught by the screw trap and 80 (9% of all captured species) by the fyke net]. The sucker catch was substantially higher in 1998, largely due to an increase in age-0 collections. For both years and methods combined, the majority of suckers were caught in August (76% in 1997 and 68% in 1998), however, numerous suckers were collected in September 1998 (25%).

- Species composition and timing: In all sampling prior to July, blue chubs dominated the catch (50-90%) for both methods in both years. Tui chubs (*Gila bicolor*) were also common (>10%) during this period in 1997 and fathead minnows (*Pimephales promelas*) were in 1998. By mid-July, the catches and the diversity of sampled species increased. In 1997, the native fishes, (blue chubs, tui chubs, and all suckers) made up 87% of the screw trap catch; in 1998, they comprised only 52%. In 1998 the sampled fish community was generally more diverse with more abundant fish species of both native (e.g., sculpin species) and non-native (e.g., yellow perch and fathead minnows) origin.

- We believe that an increase in August-September 1997 entrainment rates of large fish (>150 mm FL) resulted primarily as stressed and debilitated fish moved from severely degraded water quality conditions in Upper Klamath Lake during a fish kill. Numerous age-0 fish, which were in relatively good condition, were also collected at that time. These fish were likely stressed by poor water conditions, but may also have been moving in response to other stimuli (e.g., competitive interactions, attraction to flows, temperature, etc.). Consequently, the increased late-summer catches may, when combined with similar 1998 patterns, suggest an annual movement pattern.

- Similar to Link River entrainment study results, collections of suckers and other fishes increased dramatically in the late-summer period and declined in the fall. The highest fish catch per unit effort (CPUE) values were measured during periods when lake levels were relatively low, which is auto-correlated with late season. After sucker CPUE values reached their peaks, these values tended to decrease along with diminishing canal flows at the irrigation season's end, especially in 1997. For all fish, CPUE values were highest, in both years, after maximum A-canal flows had passed. Overall, the catches often grew with increased A-canal flow, because we filtered relatively more water during a similar sample duration, however the CPUE did not increase. Since there is not a tight correlation between flows and CPUE values, it is doubtful that fish were uniformly distributed in the waters of southern Upper Klamath Lake.

- The higher entrainment rates of age-0 suckers in the A-canal during late summer of 1998, as contrasted to 1997, corresponded to that year's higher late-summer A-canal and total south lake outflows. These data may suggest that if passive dispersal of age-0 suckers occurs, higher lake outflows in late summer (i.e., inclusive of Link River and powerhouses) would expose more suckers to the vicinity of the A-canal headworks.

- In both years, the majority of age-0 (generally <75 mm FL) suckers were entrained during late summer (August and September). Catch rates were substantially higher at night, especially in 1998. By late July and the beginning of the high sucker catch period (July 15-30), age-0 suckers averaged 45 mm FL in 1997 (range 27-88 mm) and 37 mm FL in 1998 (range 19-80 mm).

- Compared to the timing of maximum 1997 catches, the 1998 sucker collections approximated a more protracted normal distribution. The 1997 catches moved from low sucker CPUE values (<20 suckers/100 acre ft), to high values (100 suckers/100 acre ft) within a week whereas CPUE values in 1998 increased more gradually. A higher rate of sucker entrainment was evident in 1998 (e.g., >500 suckers/100 acre ft at the peak), than in 1997 (100 suckers/100 acre ft). Though the specific reasons for movement is unclear, species composition trends for all fish in 1998 also showed definite peaks, which we interpret as movement of individual species as they dispersed according to species-specific environmental or density-dependent cues. In 1997, there appears to have been one extended migration of all species, during day and night periods, which was probably greatly influenced by poor water quality conditions. Based on all this information, we speculate that some age-0 suckers probably leave the lake annually as they did in 1997 and 1998. The mechanisms affecting sucker dispersal from Upper Klamath Lake are obviously varied, complex, and interrelated. Our limited data collected in 1997 and 1998 suggest that water quality and total outflow are among the most apparent parameters influencing dispersal although there are probably other behavioral mechanisms which are not fully understood.

- We were unable to calibrate fish trapping operations through mark/recapture techniques. We therefore extrapolated the fish catches based on percent of daily flow sampled to develop entrainment indices which accounted for unsampled volumes of water and periods of time. The total 1997 A-canal entrainment index was estimated at 465,536 fish of all species and included

46,708 suckers. The 1998 entrainment index was 1,239,801 total fish and included 246,524 suckers. The larger 1998 entrainment index is primarily due to other variables previously discussed and the more numerous age-0 fish sampled in that year which probably indicates a stronger year-class strength than in 1997.

ACKNOWLEDGMENTS

The authors wish to acknowledge and thank the individuals and agencies involved in completing this work.

We thank the U.S. Bureau of Reclamation for funding this study and its staff of the Klamath Falls office: Mark Buettner for supplying insights and assisting development of the grant which funded this work, and Michael Berg, who offered advice on water quality monitoring and provided Reclamation's unpublished A-canal headworks water quality data. We also thank the Glenn-Colusa Irrigation District for the use of their rotary screw trap in 1997 and the Arcata, California office of the U.S. Fish and Wildlife Service for the use of their rotary screw trap in 1998. We thank the Klamath Tribes for the use of their fish holding tanks in 1997 and 1998. We thank the Klamath Irrigation District staff, Dave Solem and Mark Stuntebeck, for allowing access to KID's property and use of their equipment. We also appreciate their timely provision of monthly canal flow data.

We thank the officers of the Cell Tech/New Earth Company, particularly Marta and Daryl Kollman, for their progressive environmental attitude to pursue this research. Aside from the authors with Cell Tech's Research and Development department, field work was conducted by Brooke Bechen, Nathan Rice, Art Sevigny, Ryan Weider, and Cassandra Watson. Jim Carpenter and Dr. Robert Moore provided valuable reviews of earlier report drafts.

LITERATURE CITED

Bellerud, B. and M.K. Saiki. 1995. Tolerance of larval and juvenile Lost River and shortnose suckers to high pH, ammonia concentration, and temperature, and to low dissolved oxygen concentration. National Biological Service, California Pacific Science Center, Dixon Field Station; Dixon CA. 90 pp.

Bienz, C.S. and J.S. Ziller. 1987. Status of three lacustrine sucker species (Catostomidae). The Klamath Tribes and Oregon Department of Fish and Wildlife report. 34 pp.

Buettner M.E. and G. Scoppettone. 1990. Life history and status of catostomids in Upper Klamath Lake, Oregon. The National Fisheries Research Center, Reno NV. 108 pp.

Buettner M.E. 1997. Upper Klamath Lake fish die-off, 3rd consecutive year – 1997. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls OR. 8 pp.

Castleberry D.T. and J.J. Cech Jr. 1993. Critical thermal maxima and oxygen minima of five fishes from the Upper Klamath Basin. California Fish and Game 78(4):145-152.

Davis, J.C. 1975. Minimal dissolved oxygen criteria of aquatic life with emphasis on Canadian species: a review. J. Fish Resource Board of Canada. Volume 32(12):2295-2328.

DeLonay A.J. and E.E. Little. 1997. Swimming performance of juvenile shortnose suckers (*Chasmistes brevirostris* Cope) and Lost River suckers (*Deltistes luxatus* Cope). U.S. Geological Survey, Biological Resources Division, Midwest Science Center, Columbia MO. 11 pp.

Falter, M.A. and J. Cech. 1991. Maximum pH tolerance of three Klamath Basin Fishes. Copeia 4: 1109-1111.

Gearheart, R.A., J.K. Anderson, M.G. Forbes, M. Osburn, and D. Oros. 1995. Watershed strategies for improving water quality in Upper Klamath Lake, Oregon. Humboldt State University, Environmental Resources Engineering Department. Arcata CA. Volume I. 42pp.

Green, M.L. 1998. 1997 Klamath project sucker salvage report. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls OR. annual report. 16 pp.

Gutermuth, B., D. Beckstrand, and C. Watson. 1998. New Earth harvest site monitoring 1996-1997. New Earth/Cell Tech Research and Development dept., Final technical report to the U.S. Fish and Wildlife Service. 148pp.

Gutermuth B., C. Watson, and R. Weider. 1999. Link River hydroelectric project eastside and westside powerhouses annual entrainment study report – to the U.S. Fish and Wildlife Service. New Earth/Cell Tech: Research and Development, Klamath Falls OR. In collaboration with J. Kelly of PacifiCorp Environmental Services, Portland OR. 89 pp.

Harris, P.M. and D.F. Markle. 1991. Quantitative estimates of fish transported from Upper Klamath Lake through the A-canal, Klamath Project. Department of Fisheries and Wildlife, Oregon State University, Corvallis OR. report to the U.S. Bureau of Reclamation contract No. 0-FG-20-09630. 63 pp.

Herman R.L. and F.P. Meyer. 1990. Fish kills due to natural causes. Pages 41-44 *in* F.P. Meyer and L.A. Barclay, eds. Field manual for investigation of fish kills. US Department of the Interior - USFWS resource publication 177. 122 pp.

Kann, J. and V.H. Smith. 1993. Chlorophyll as a predictor of elevated pH in a hypertrophic lake: estimating the probability of exceeding critical values for fish success. Klamath Tribes, Chiloquin, OR. Research Report: KT-93-02. 22 pp.

Kann J. 1997. Ecology and water quality dynamics of a shallow hypereutrophic lake dominated by cyanobacteria (*Aphanizomenon flos-aquae*). Ph.D. dissertation, University of North Carolina, Chapel Hill NC. 110 pp.

Laenen A. and A.P. LeTourneau. 1996. Upper Klamath Basin nutrient-loading study – estimate of wind-induced resuspension of bed sediment during periods of low lake elevation. U.S.G.S. Open-File Report 95-414. Portland OR.

Markle, D.F. and D. C. Simon. 1993. Preliminary studies of systematics and juvenile ecology of Upper Klamath Lake suckers. Department of Fisheries and Wildlife, Oregon State University, Corvallis OR. 128 pp.

Markle, D.F. and D.C. Simon 1994. Annual Report: Larval and juvenile ecology of Upper Klamath Lake suckers. Department of Fisheries and Wildlife, Oregon State University, Corvallis OR.

Martin B.A. 1997. Effects of ambient water quality on the endangered Lost River sucker (*Deltistes luxatus*) in Upper Klamath Lake, Oregon. Masters thesis, Humboldt State University, Arcata CA. 55 pp.

Monda, D. and M.K. Saiki. 1993. Tolerance of juvenile Lost River and shortnose suckers to high pH, ammonia concentration, and temperature, and to low dissolved oxygen concentration. Final report prepared by the U.S. Fish and Wildlife Service for the U.S. Bureau of Reclamation, Denver CO and Klamath Falls OR. 89 pp.

Peck, B.J. 1999a. Klamath irrigation project sucker salvage and North Canal Langell Valley fish survey report - 1998. U.S. Bureau of Reclamation, Klamath Basin Area Office, Klamath Falls OR. annual report. 27 pp.

Peck, B.J. 1999b. Biotelemetry studies of suckers and redband trout in Upper Klamath Lake in 1993-1998. abstract presented *at* the third Klamath Basin watershed restoration and research conference. Klamath Basin Ecosystem Restoration office. March 1999.

Simon, D.C., M.R. Terwilliger, P. Murtaugh, and D.F. Markle. 1998. Larval and juvenile ecology of Upper Klamath Lake Suckers – annual report: 1997. Department of Fisheries and Wildlife, Oregon State University, Corvallis OR. pp. 109.

Stewart, N.E., D.L. Shumway, and P. Doudoroff. 1967. Influence of oxygen concentration on the growth of juvenile largemouth bass. Journal of the Fisheries Research Board of Canada 24(3): 475-494.

U.S. Fish and Wildlife Service (USFWS). 1988. Federal Register: Endangered and threatened wildlife and plants; determination of endangered status for the shortnose sucker and Lost River sucker. 53(137): 27130-27134.

U.S. Fish and Wildlife Service (USFWS). 1992. Formal consultation on the effects of the long-term operation of the Klamath project on the Lost River sucker, shortnose sucker, bald eagle, and American peregrine falcon. Region 1 office, Portland OR. 48 pp.

U.S. Fish and Wildlife Service (USFWS). 1993. Recovery Plan – Lost River Sucker *Deltistes luxatus* and Shortnose Sucker *Chasmistes brevirostris*. K. Stubbs and R. White editors. U.S. Department of the Interior, Fish and Wildlife Service, Region One, Portland OR. 108 pp.

U.S. Fish and Wildlife Service (USFWS). 1996. Formal consultation on PacifiCorp and the New Earth Company operations, as permitted by Bureau of Reclamation, for the Lost River sucker and shortnose sucker. Klamath Basin Ecosystem Restoration Office, Klamath Falls OR. 56 pp.

U.S. Geological Survey (USGS). 1996. Upper Klamath Lake fish kill - 8 August to 3 October 1996. Reno Field Station Study Bulletin No. 96-2. Biological Resources Division, Reno Field Station, Reno NV. 15 pp.

U.S. Geological Survey (USGS). 1997. Spawning migration and status of adult Lost River and shortnose suckers in Upper Klamath Lake, February - May 1997. Reno Field Station Study Bulletin No. 97-1. Biological Resources Division, Northwest Biological Science Center, Reno NV. 20 pp.

Vogel, D.A. 1997. Preliminary investigation on fish entrainment into the A-Canal on Upper Klamath Lake. Natural Resource Scientists, Inc., Red Bluff, CA. 54 pp.

<u>Personal Communications:</u>

Mr. David Solem, manager, Klamath Irrigation District, Klamath Falls, Oregon.

FIGURES

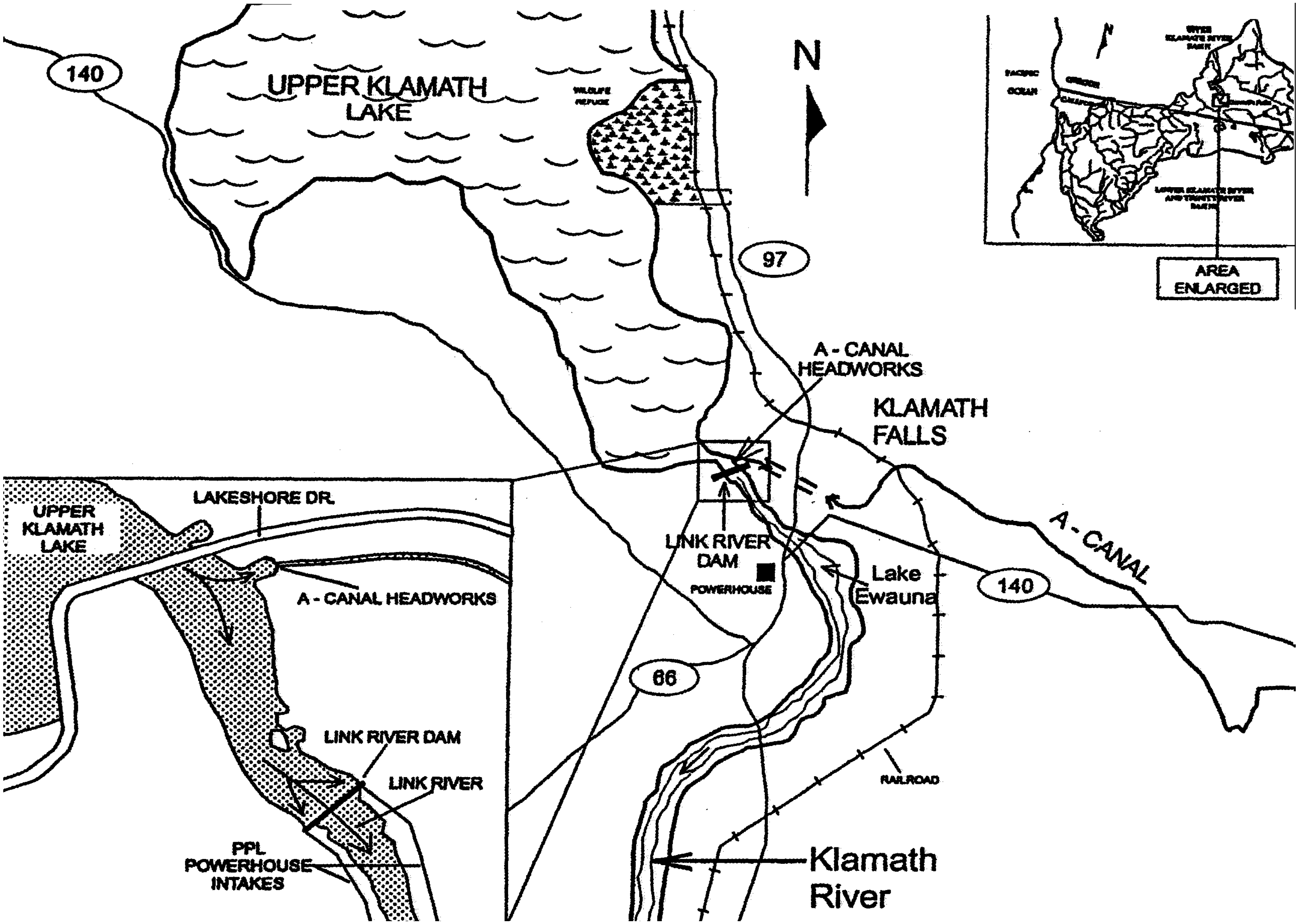


Figure 1. Location of the A-Canal Headworks and Link River Dam at the southern end of Upper Klamath Lake (from Vogel 1997).

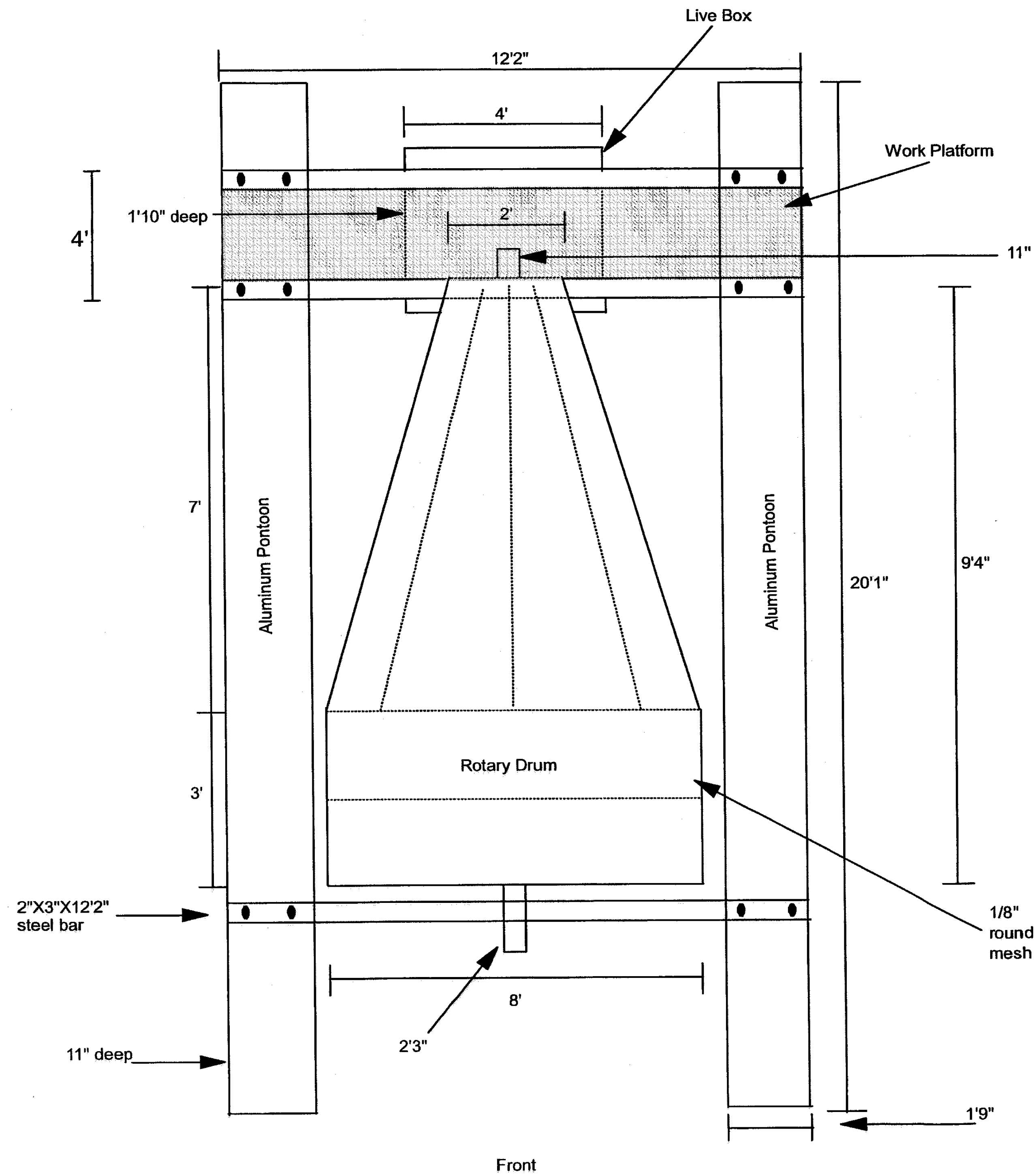


Figure 2. Plan view and dimensions for an eight-foot diameter rotary screw trap (not to scale

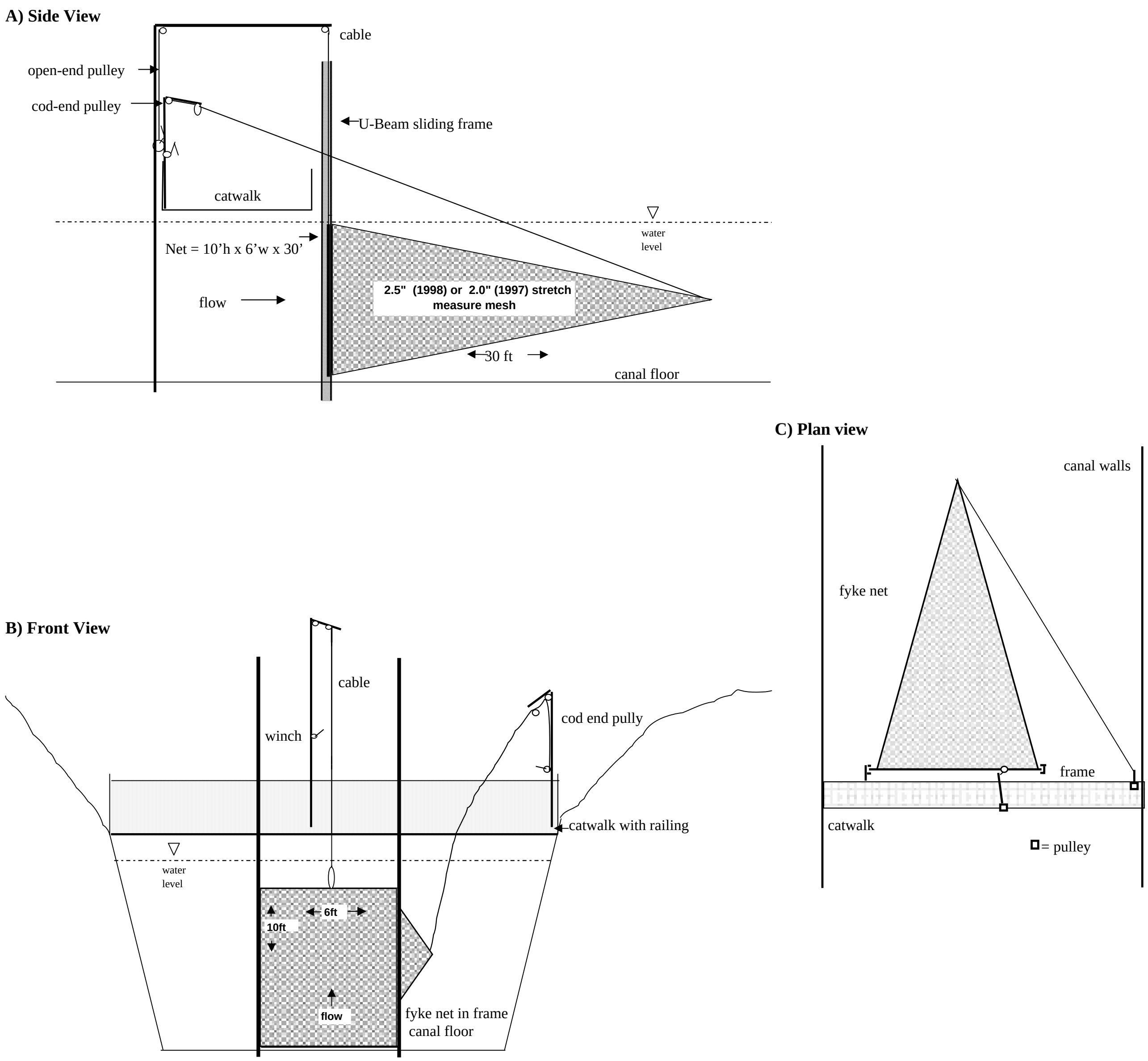
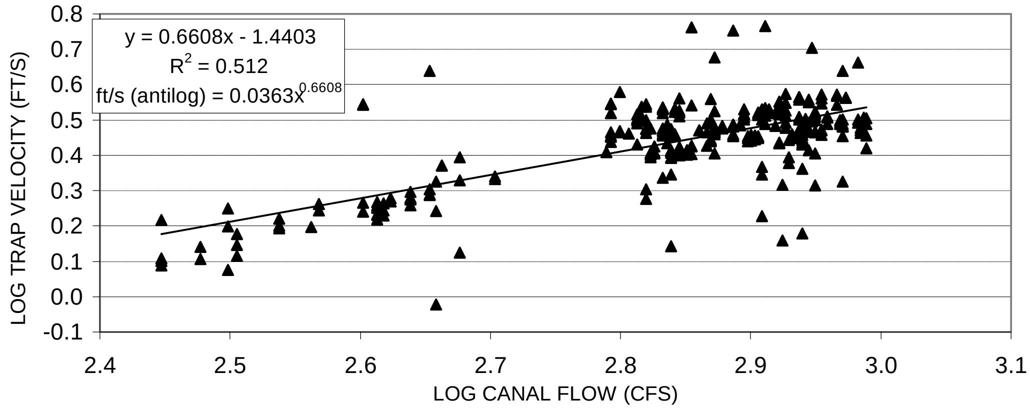
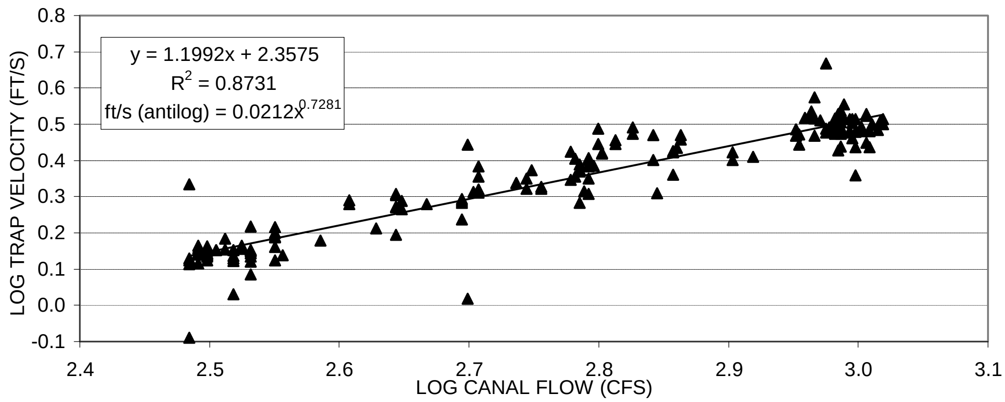


Figure 3. Schematic of the A-Canal fyke net structure. A) Side view, B) Front view, and C) Plan view.

A) 1997 Log_{10} screw trap velocity (ft/s) vs. canal flow (cfs)



B) 1998 Log_{10} screw trap velocity (ft/s) vs. canal flow (cfs)



C) Screw trap and fyke net velocities (ft/s) vs. canal flow rate (cfs)

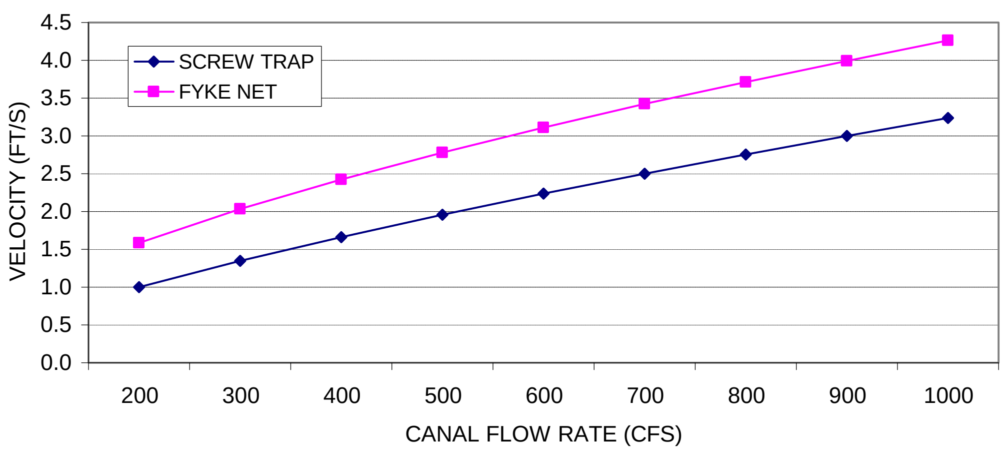


Figure 4. Correlation between the Log_{10} of screw trap velocities and canal flow rate for 1997 (A) and 1998 (B). Graph C) presents screw trap and fyke net velocities at corresponding canal flow rates. Screw trap velocities were lower due to the trap sampling the upper four feet of the water column.

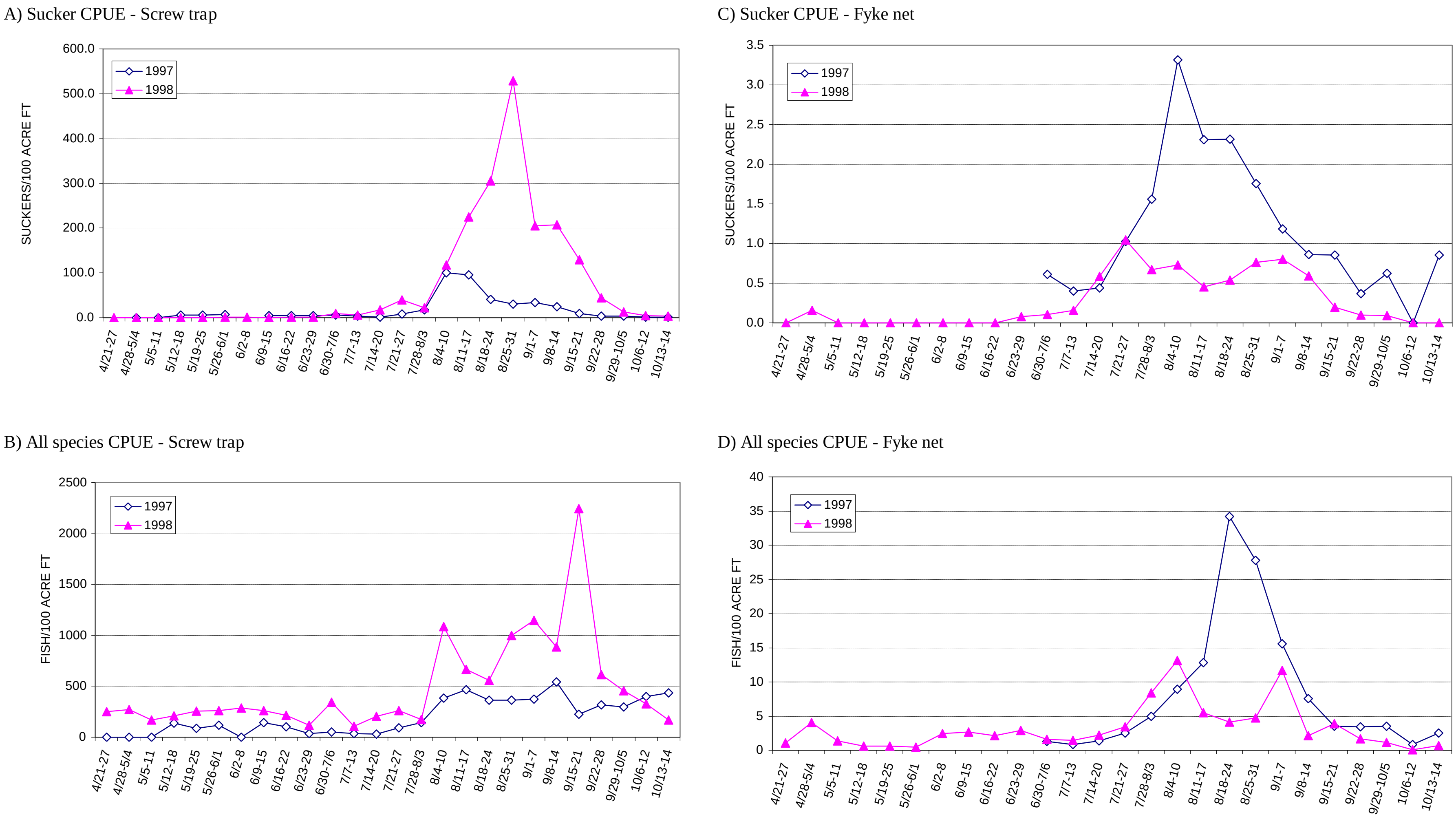
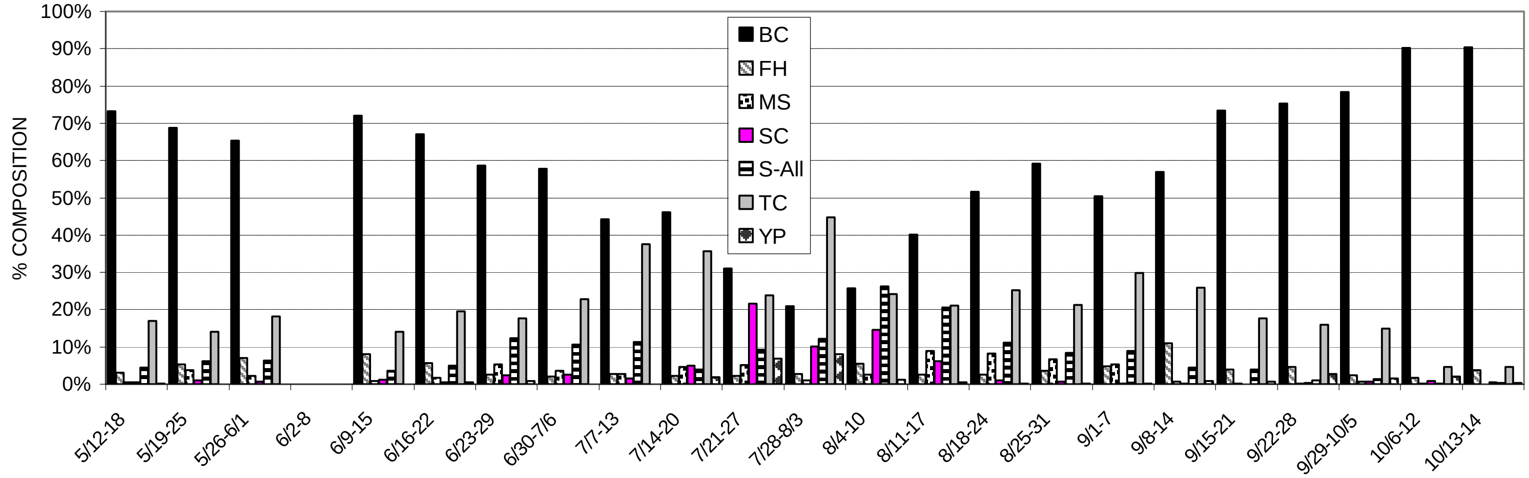


Figure 5. Sucker and All species CPUE values for screw trap (A&B) and fyke net (C&D) sampling in 1997 and 1998. Dates from 1997 were used to represent both years. Weeks in 1998 run one date behind.

A) 1997 screw trap composition by percent



B) 1998 screw trap composition by percent

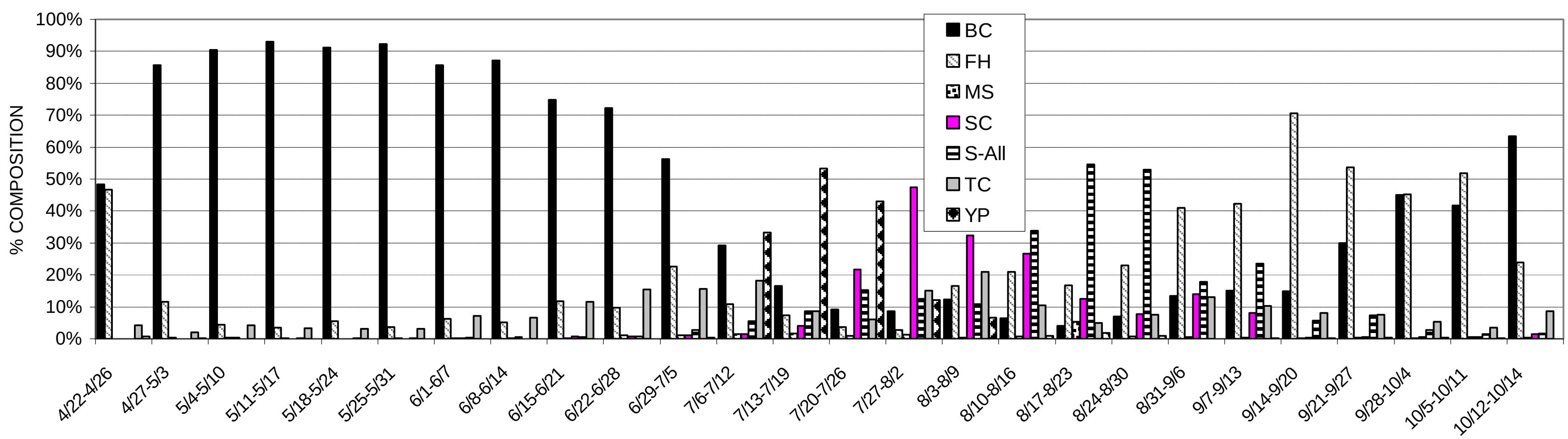
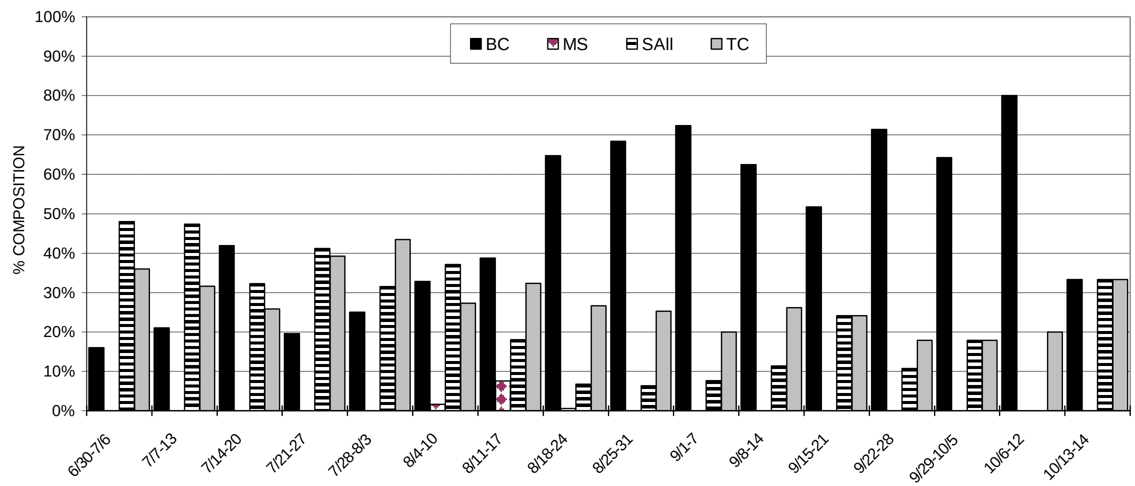


Figure 6. 1997 (A) and 1998 (B) weekly screw trap species composition. (Table 1 includes species codes

A) 1997 fyke net composition by percent



B) 1998 fyke net composition by percent

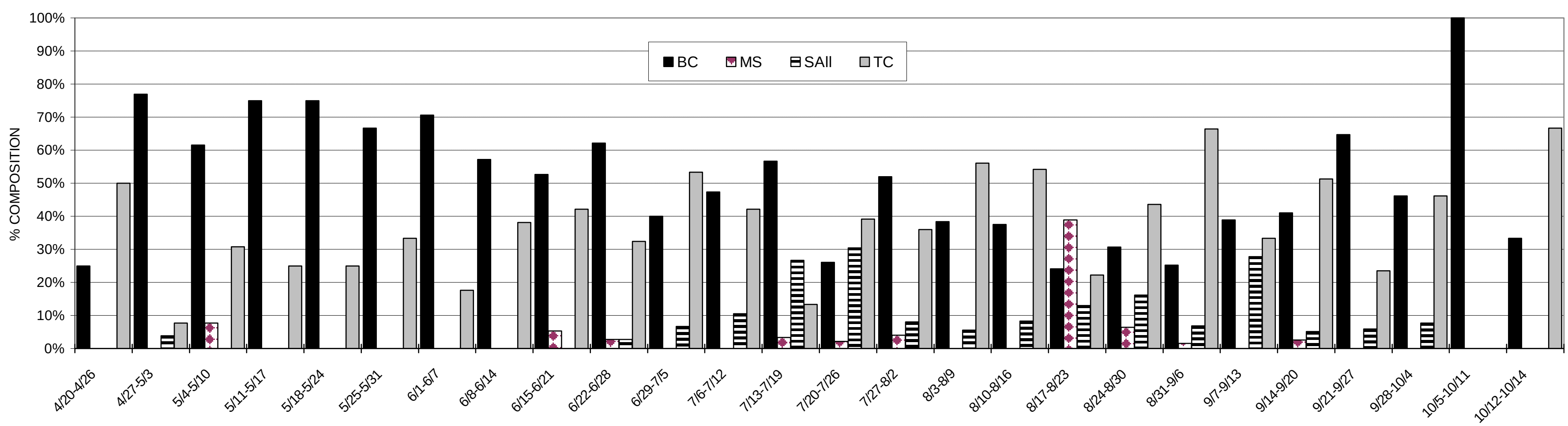
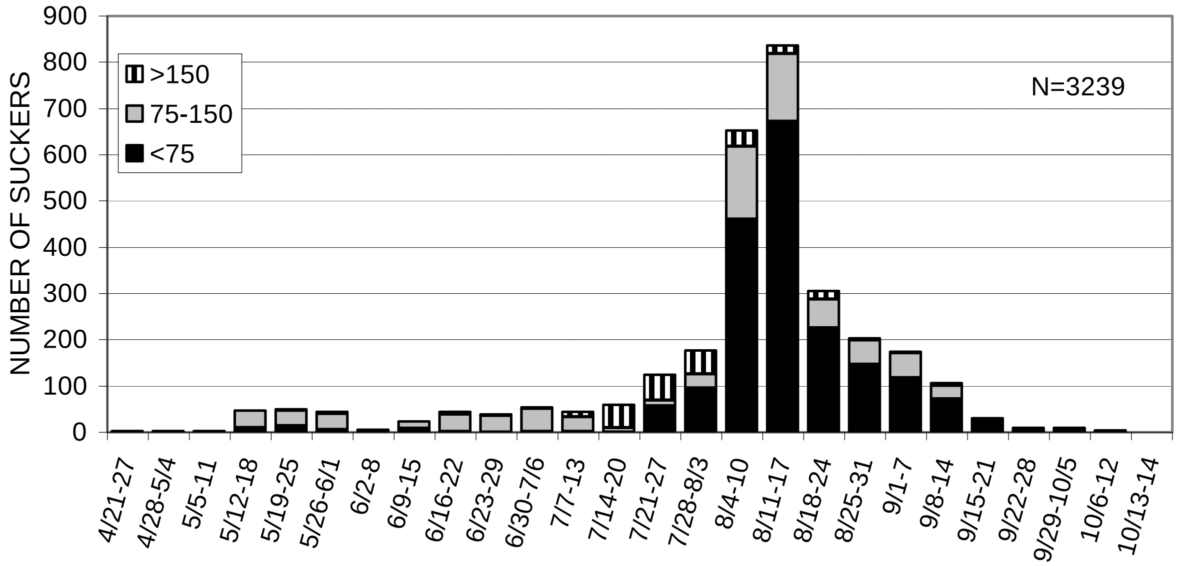


Figure 7 . 1997 (A) and 1998 (B) weekly fyke net species composition. (Table 1 includes species codes.)

A) 1997 screw trap sucker catch by size class



B) 1998 screw trap sucker catch by size class

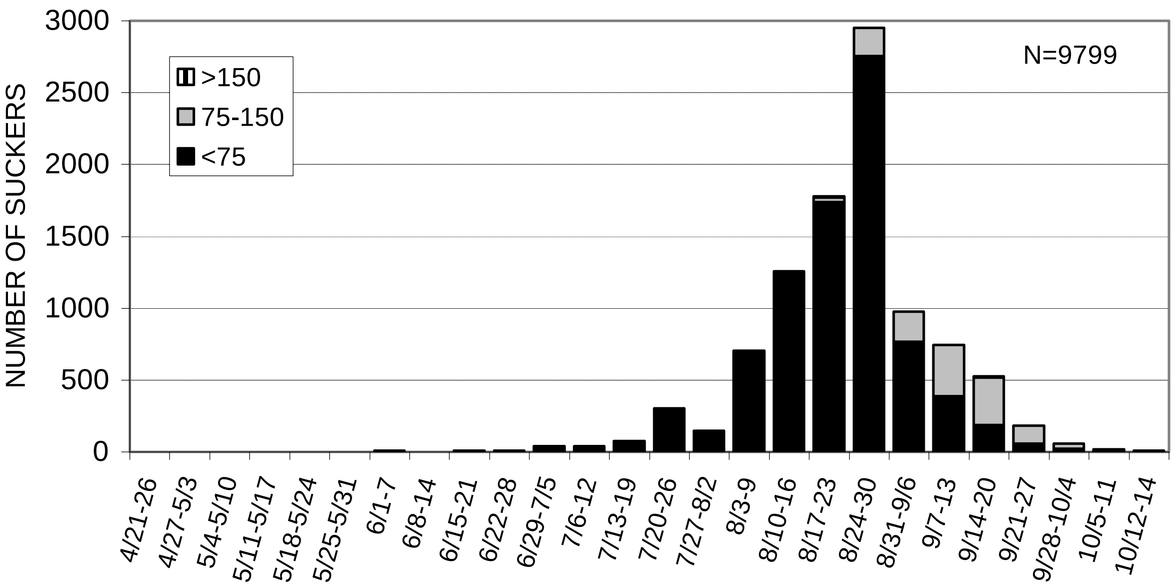


Figure 8. 1997 (A) and 1998 (B) weekly screw trap sucker catches by size class. Size classes are defined as: <75 mm, 75-150 mm, and >150 mm fork length. Increases in the 75-150 mm size class during Sept.-Oct. 1998 primarily represents age-0 fish that have grown to >75 mm FL

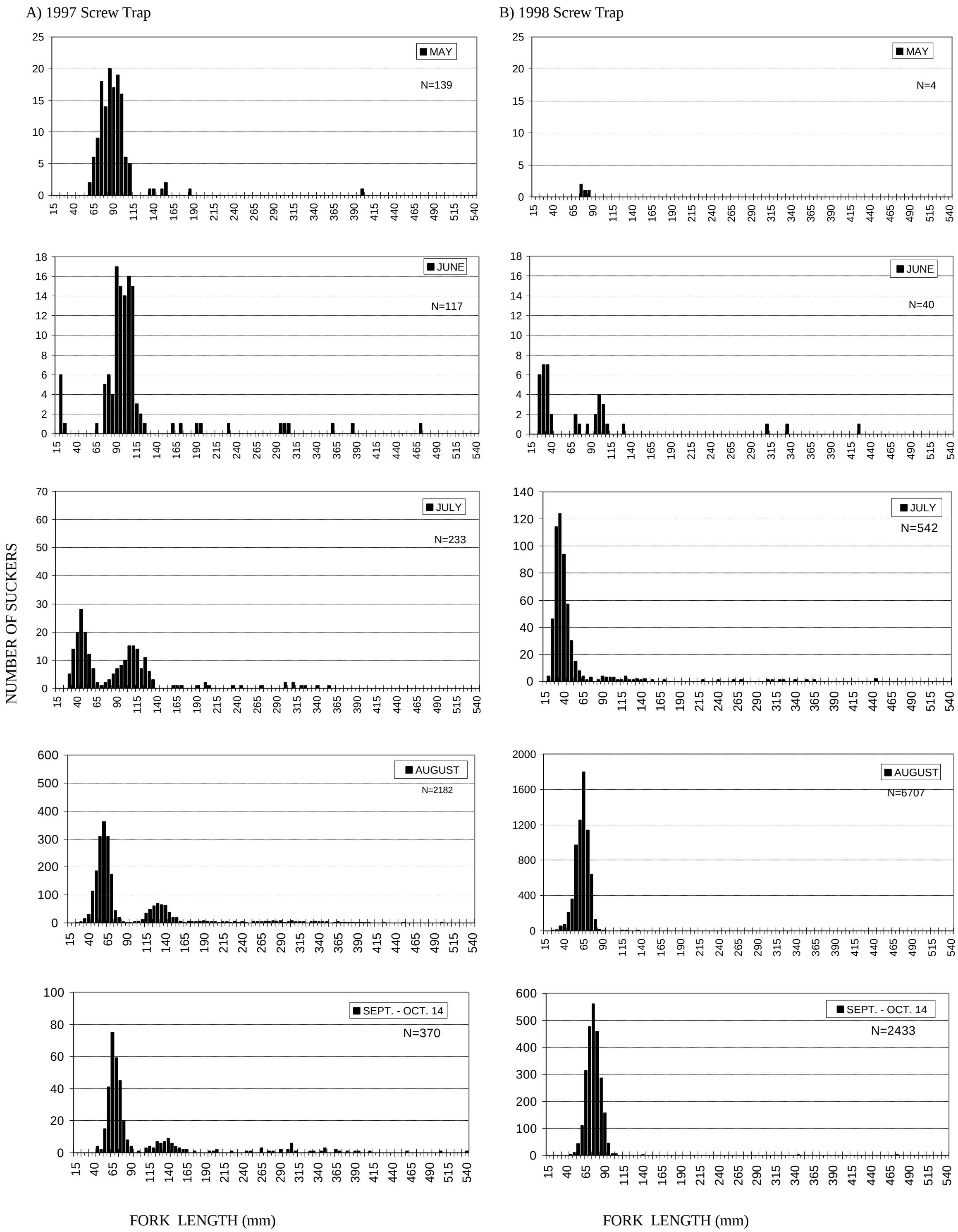


Figure 9. 1997 (A) and 1998 (B) monthly screw trap sucker length frequency histograms. N = monthly screw trap total catch.

A) 1997 Fyke Net Sucker Length Frequency

B) 1998 Fyke Net Sucker Length Frequency

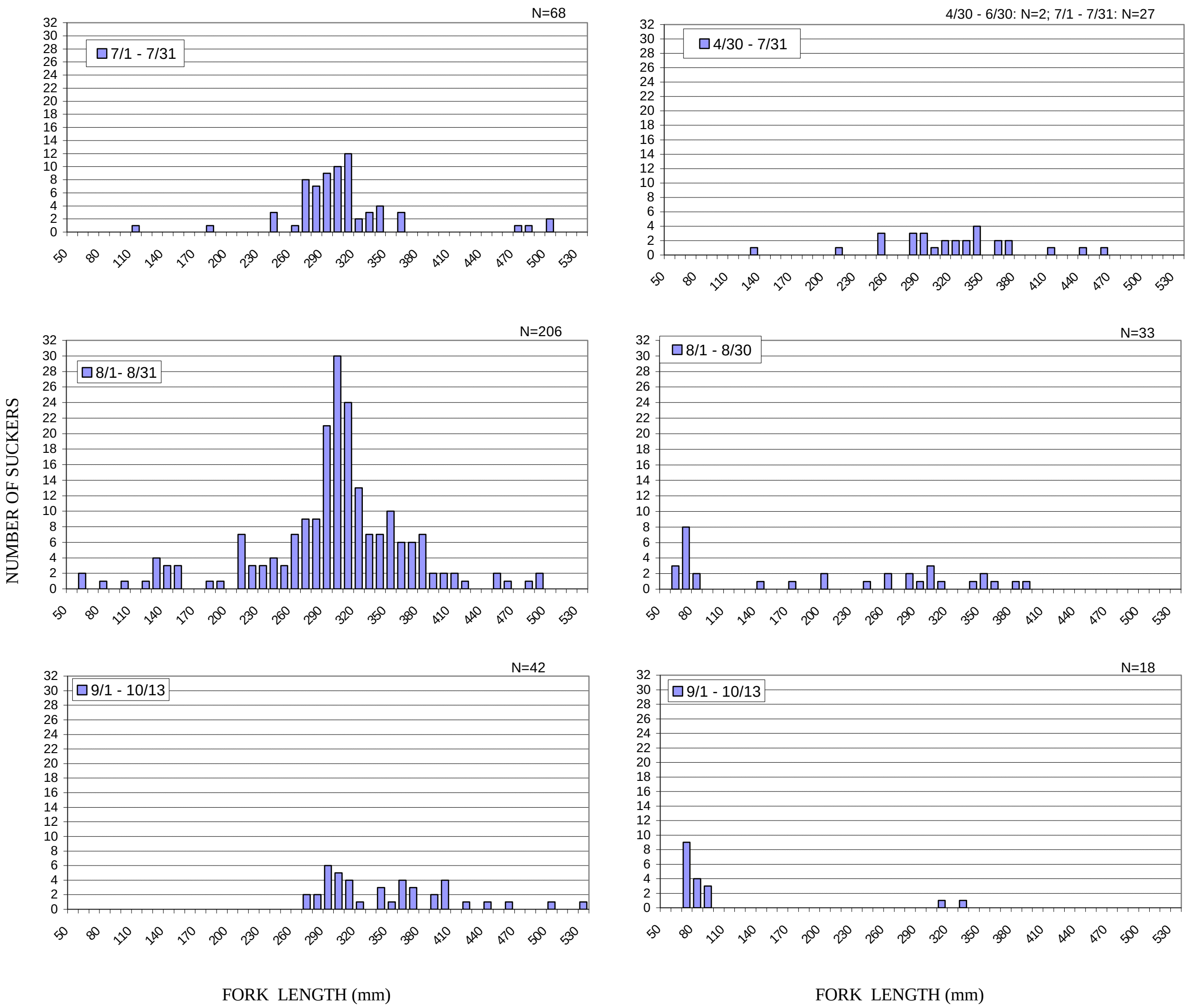
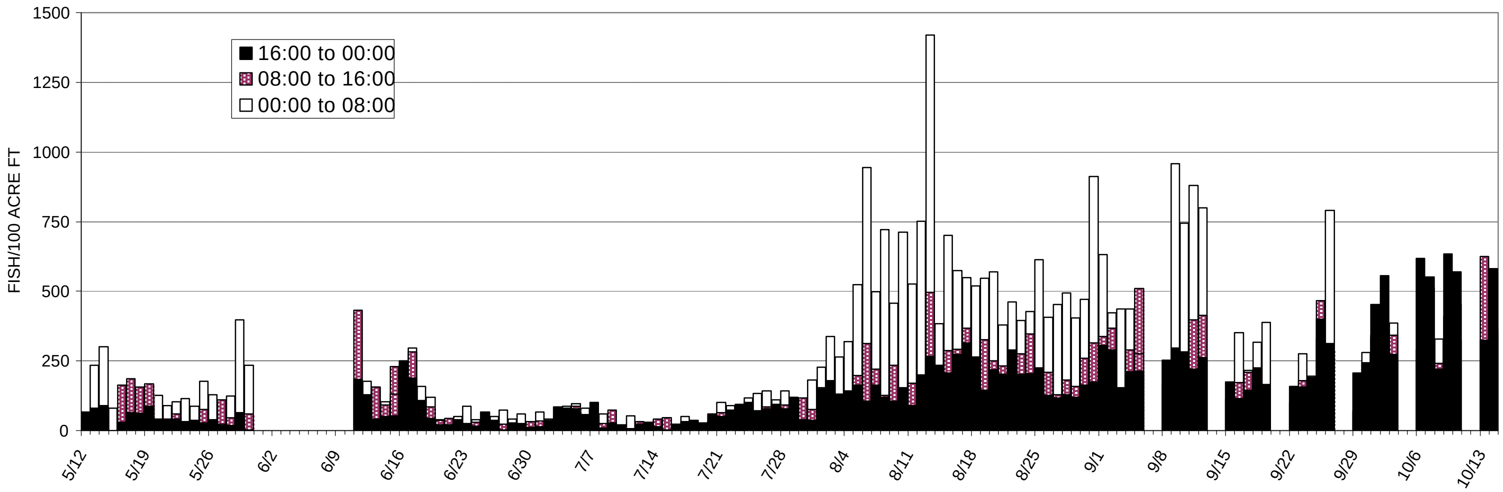


Figure 10. 1997 (A) and 1998 (B) monthly fyke net sucker length frequency histograms. N = monthly fyke net total catch.

A) 1997 timing results



B) 1998 timing results

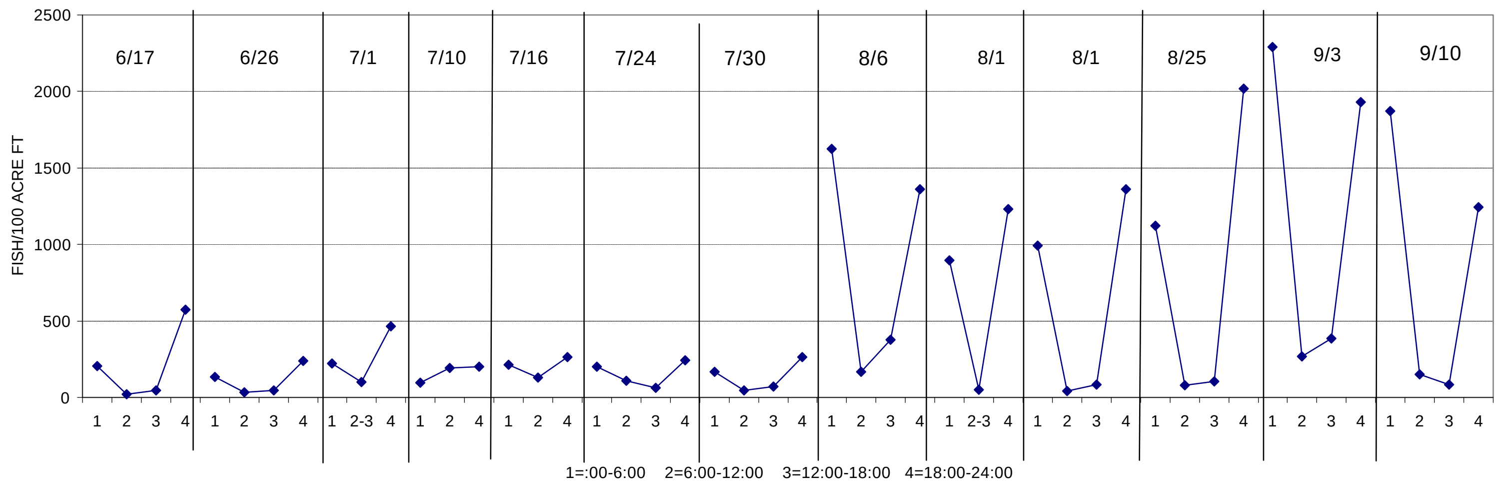
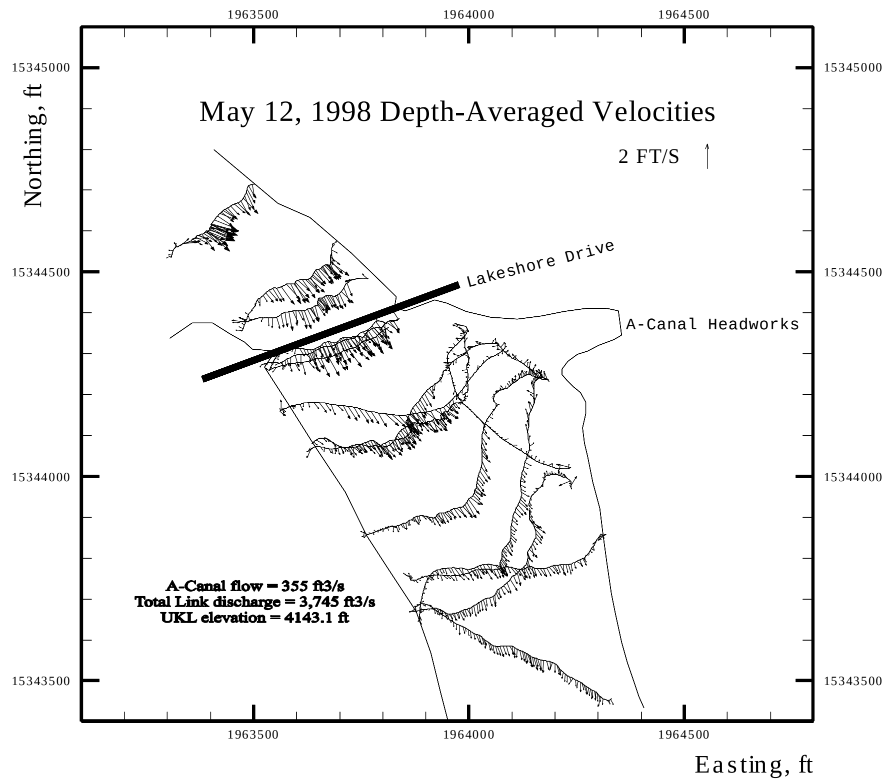


Figure 11. 1997 (A) and 1998 (B) day and night catch rates for the screw trap.

A)



B)

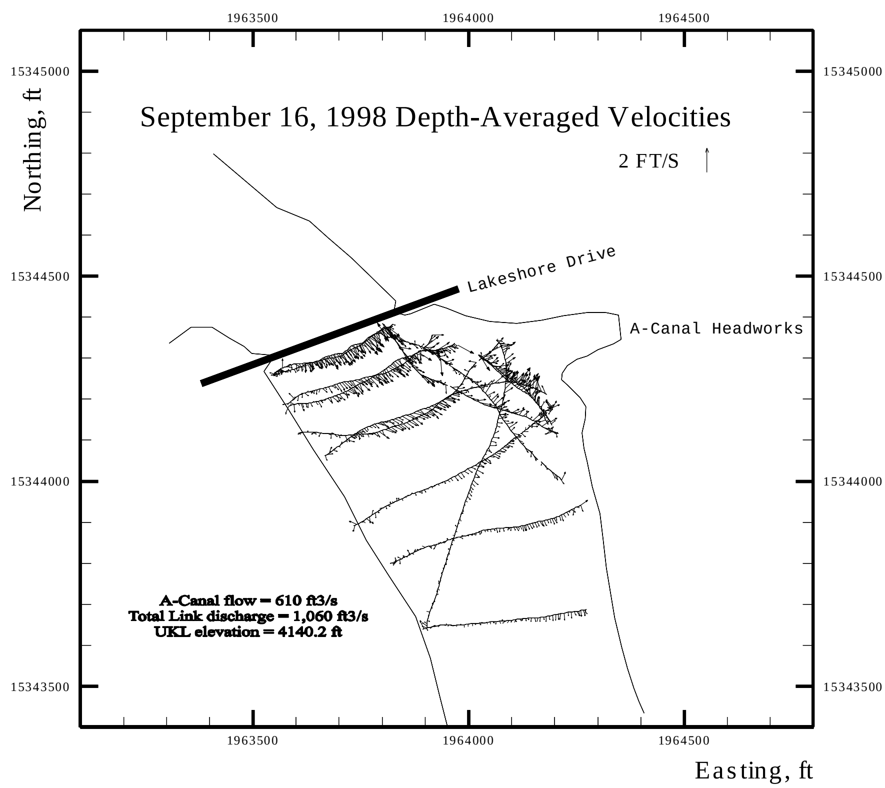
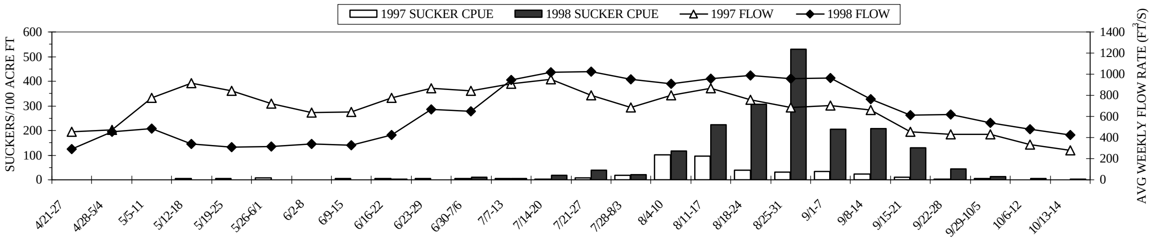
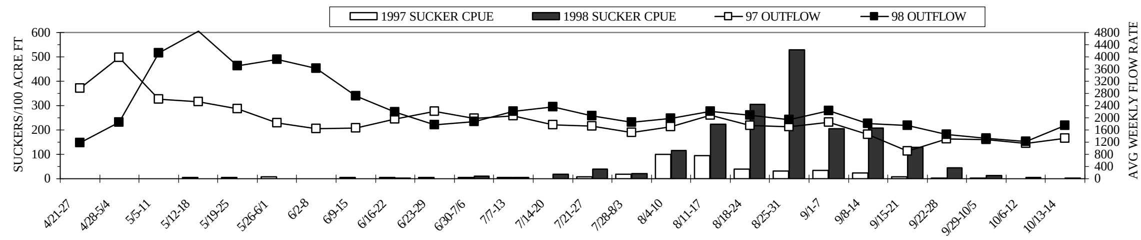


Figure 12. Southern Upper Klamath Lake velocity vectors at Link River Dam and A-Canal outflows in May (A) and September (B), 1998 (from U.S. Bureau of Reclamation, Denver Office, unpublished data).

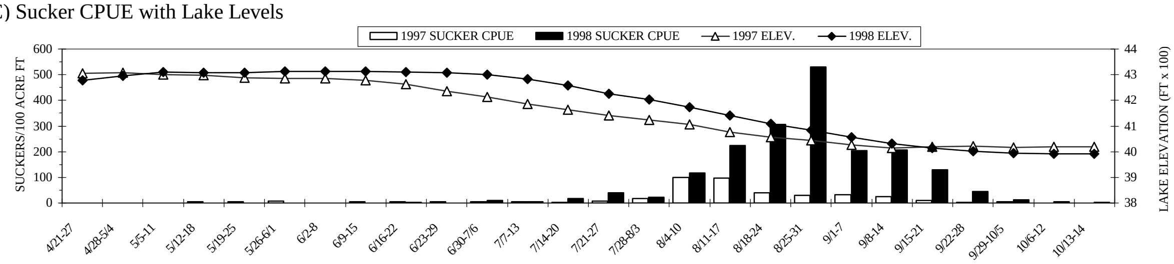
A) Sucker CPUE with A-Canal flow



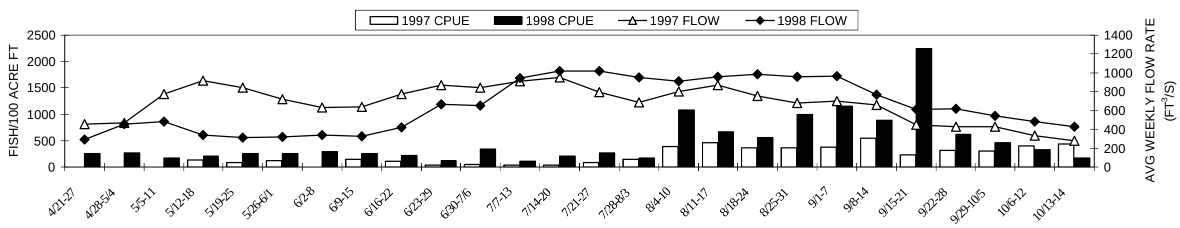
B) Sucker CPUE with all Lake Outflows (A-canal + Link River and both powerhouses)



C) Sucker CPUE with Lake Levels



D) All fish CPUE with A-Canal flow



E) All fish CPUE with Lake Levels

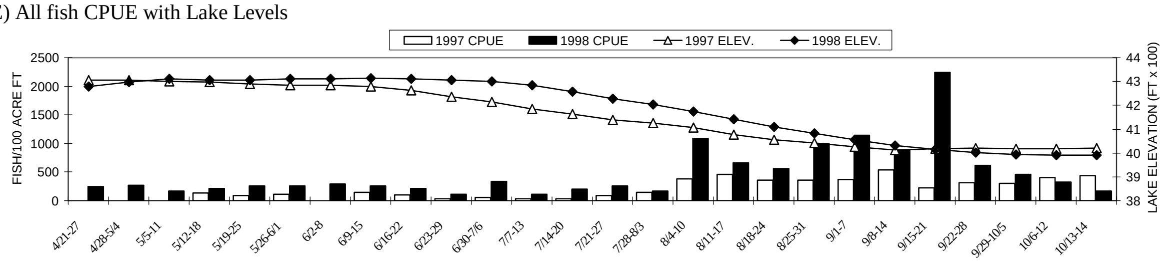
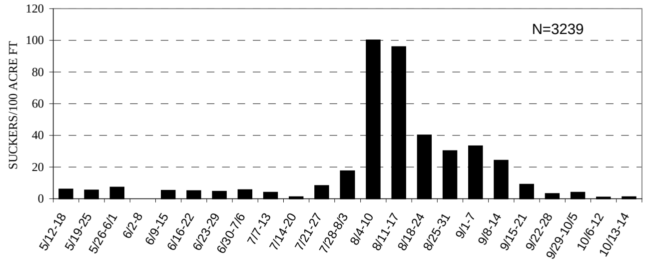
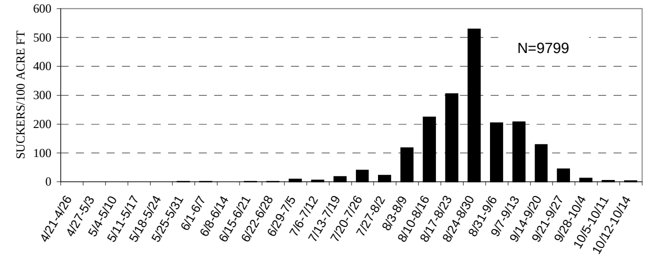


Figure 13. 1997 and 1998 sucker (A, B, and C) and all fish (D and E) mean weekly screw trap CPUE values (number/100 acre ft) graphed against mean weekly A-canal flow (ft^3/s), total Upper Klamath Lake outflow (A-canal and all Link River flows combined) and Upper Klamath Lake elevation (ft).

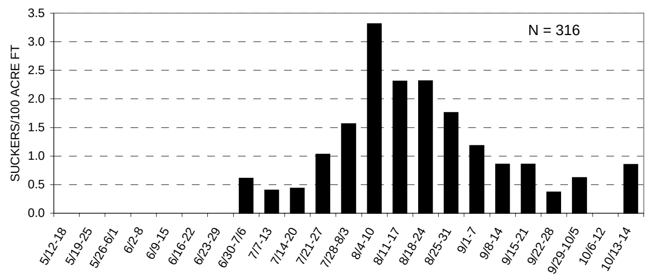
A) 1997 screw trap



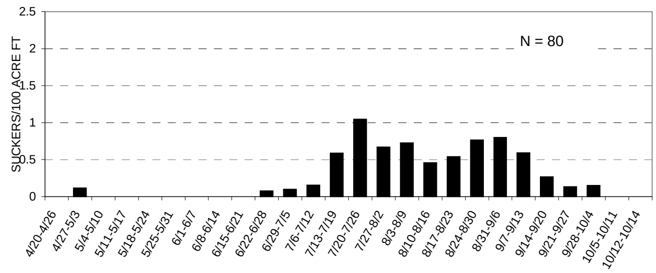
C) 1998 screw trap



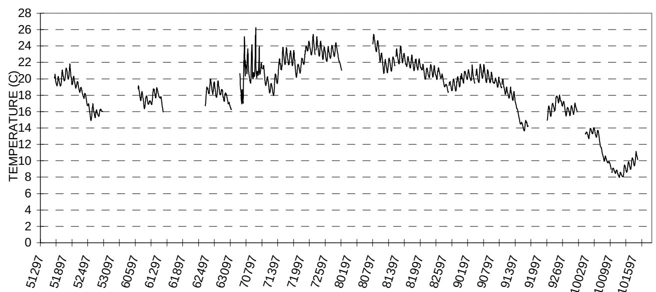
B) 1997 fyke net



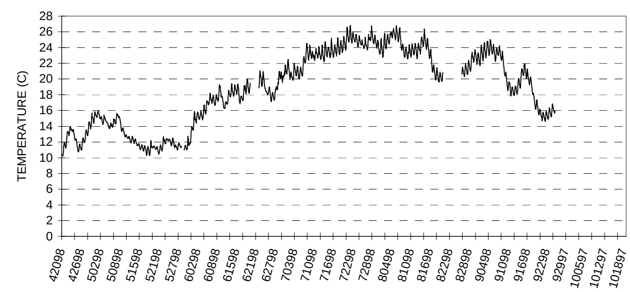
D) 1998 fyke net



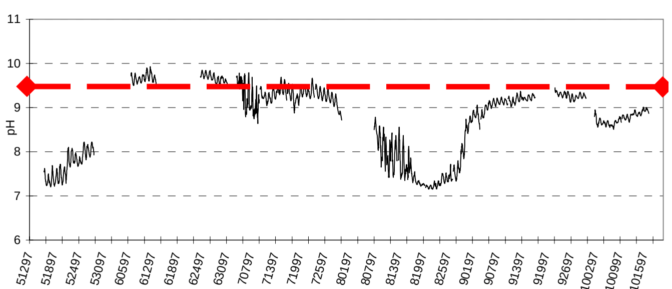
E) 1997 temperature



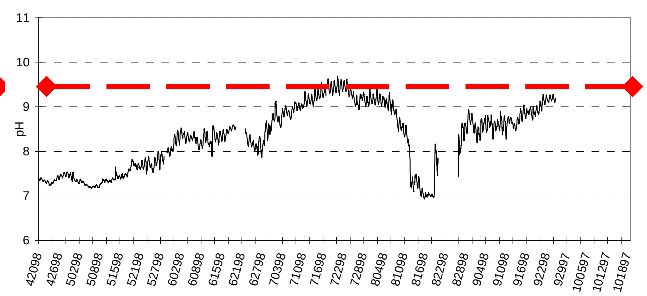
F) 1998 temperature



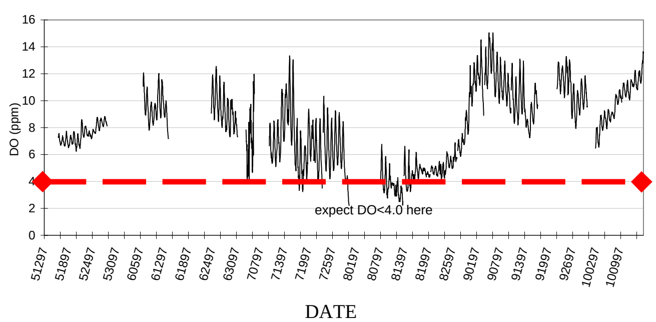
G) 1997 pH



H) 1998 pH



I) 1997 dissolved oxygen



J) 1998 dissolved oxygen

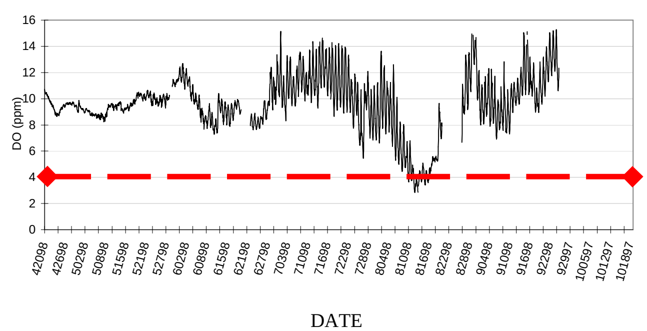


Figure 14. 1997 and 1998 screw trap and fyke net sucker CPUE values (A-D) with A-canal hourly temperature, pH, and dissolved oxygen data (E-J). Highlighted lines in water quality graphs represent stressful limits to suckers (>9.5 for pH, and <4.0 for DO). Water quality from U.S. Reclamation unpublished data. NOTE: 1997 -7/30/97 to 8/7/97 no data, however start and end DO values were <4.0 ppm DO.

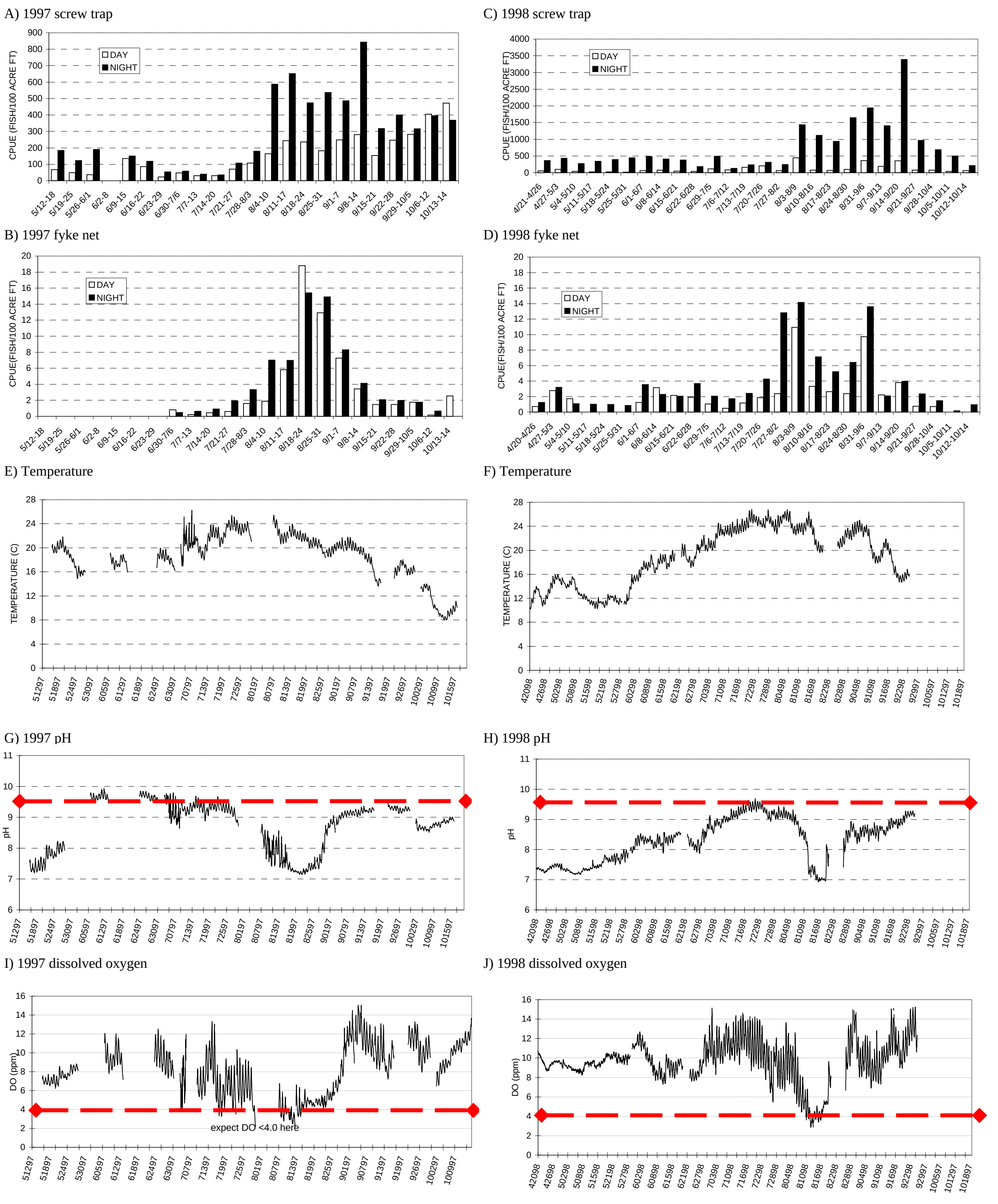


Figure 15. 1997 and 1998 screw trap and fyke net all fish CPUE values for day and night periods (A-D) with A-canal hourly temperature, pH, and dissolved oxygen data (E-J). Highlighted lines in water quality graphs represent stressful limits to suckers (> 9.5 for pH, and < 4.0 for DO). Water quality from U.S. Reclamation unpublished data. NOTE: 7/30/97 to 8/7/97 no data, however start and end DO values were <4.0 ppm DO.

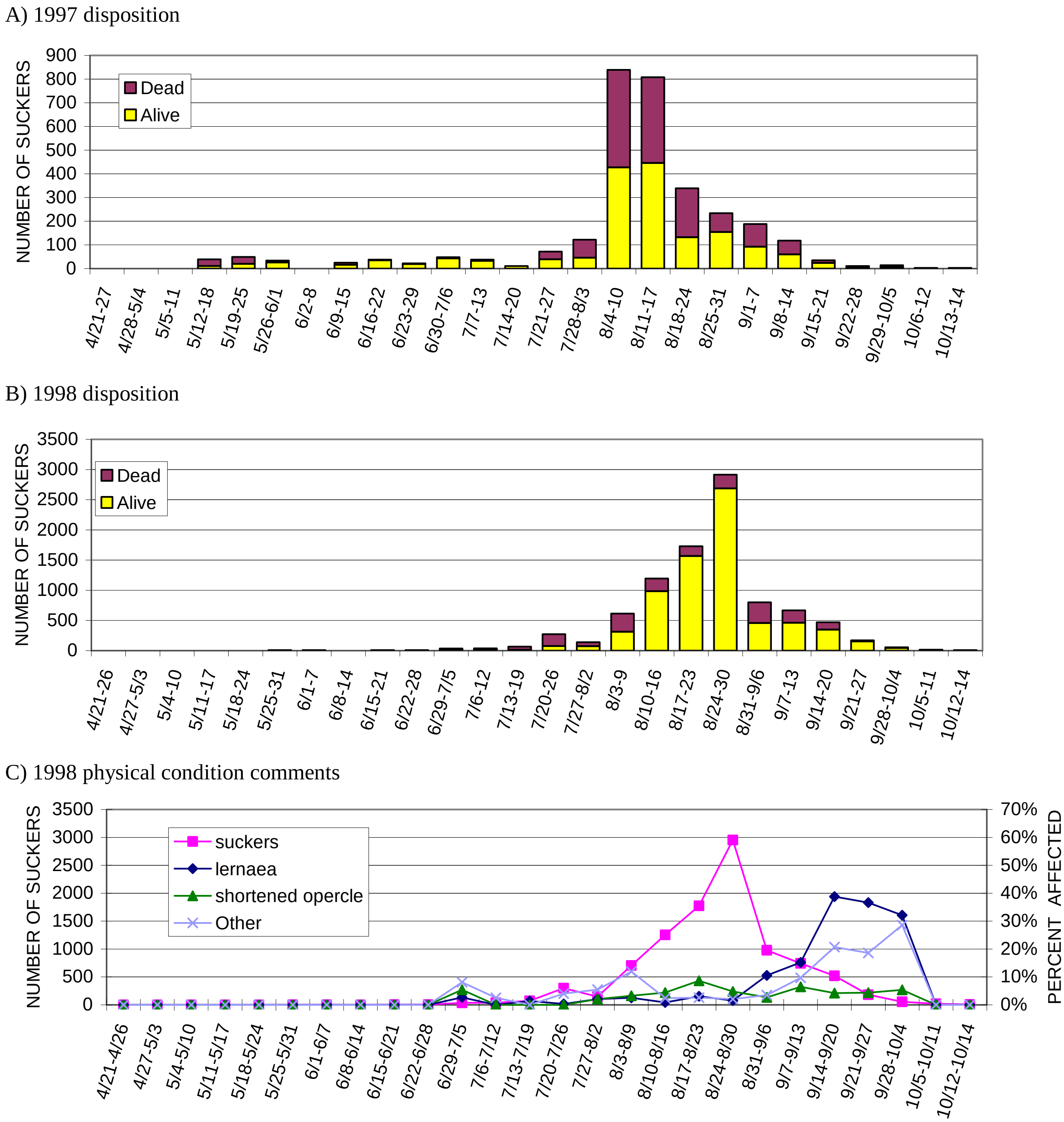


Figure 16. 1997 (A) and 1998 (B) weekly screw trap sucker disposition and 1998 weekly sucker physical condition comments (C). 'Other' includes: trematode cysts, destroyed fins, eye(s) missing, fungus, lamprey wounds, leeches, and descaling.

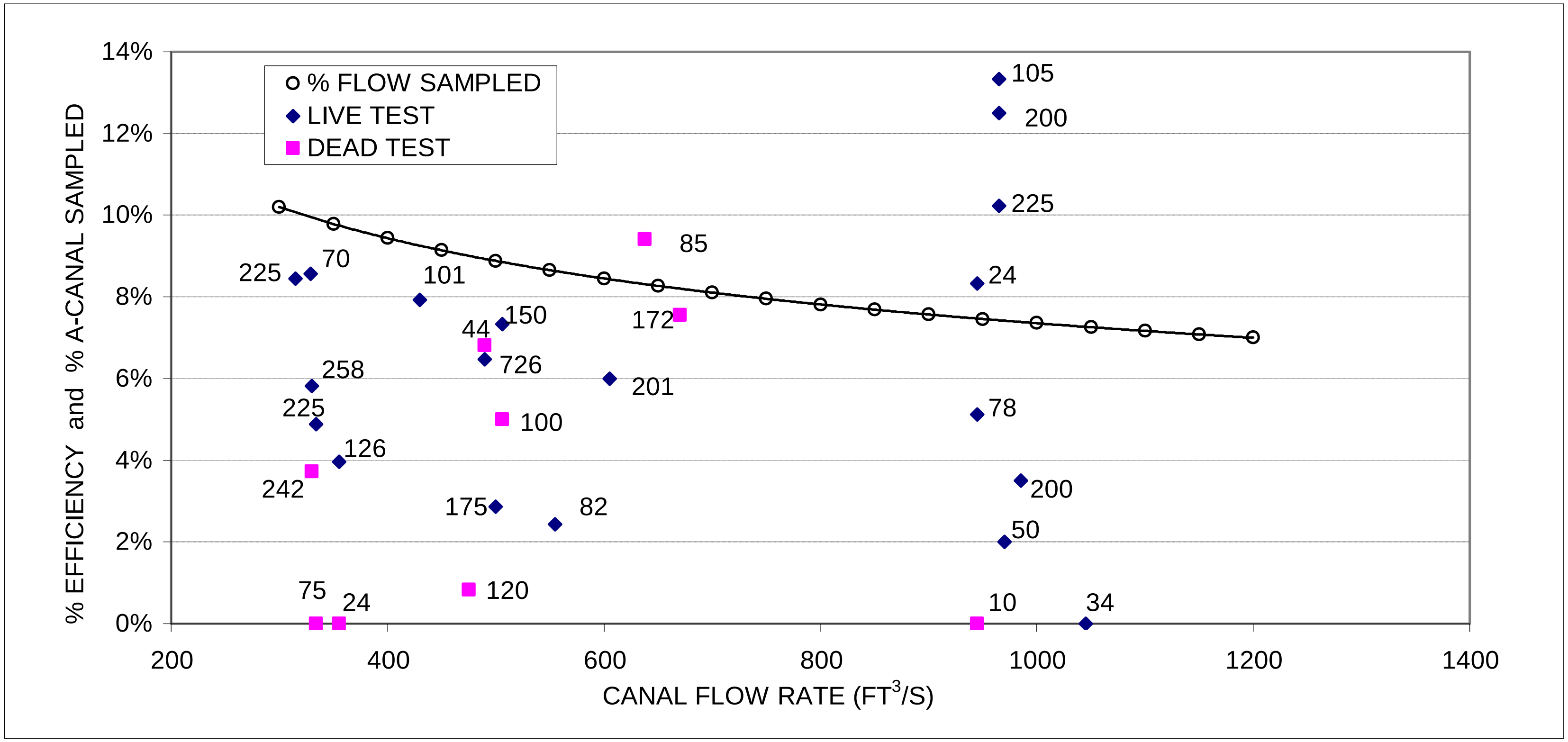
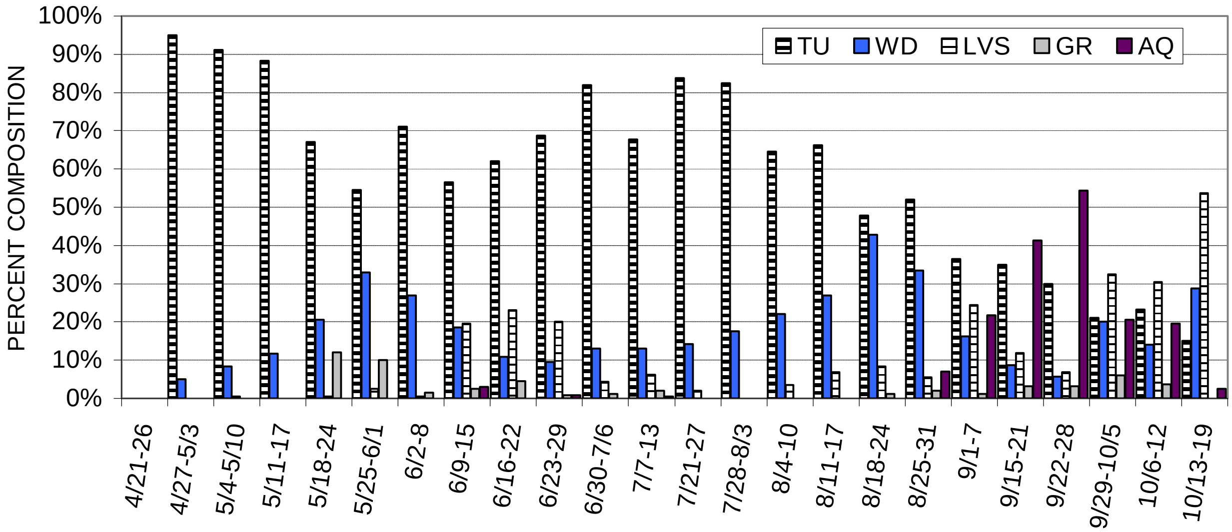


Figure 17. Screw trap efficiency test results run in 1998 using live and dead test fish. The percent of the canal sampled by the screw trap is depicted by the line with open circles. Numbers adjacent to each data point represent the number of fish used in that test.

A) Debris composition



B) Debris loading

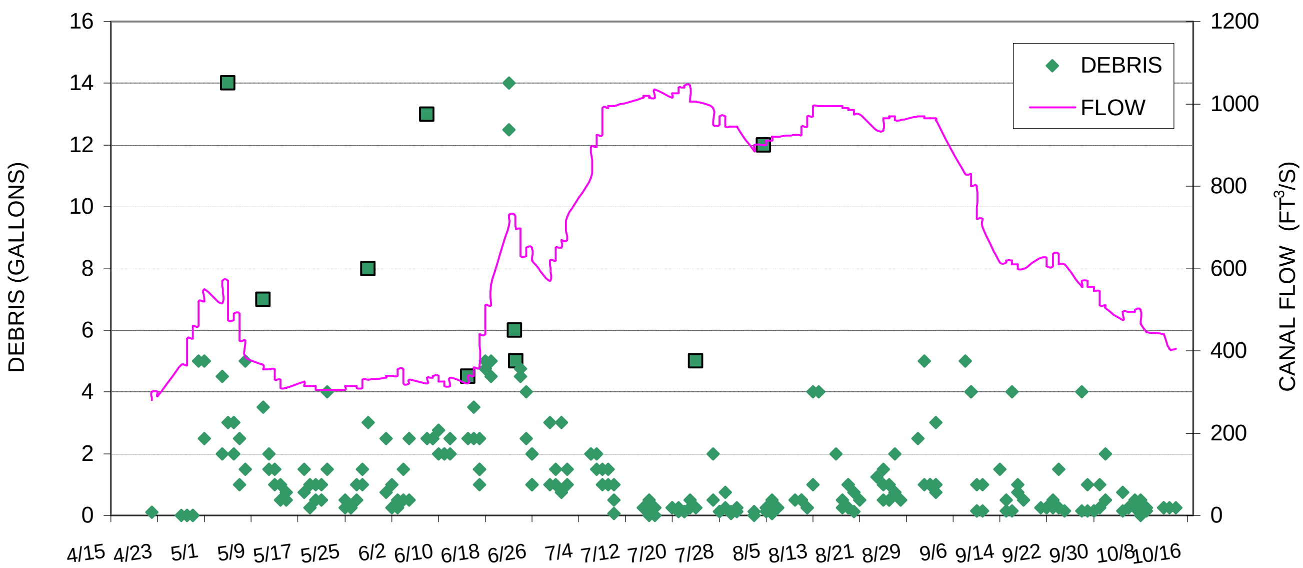
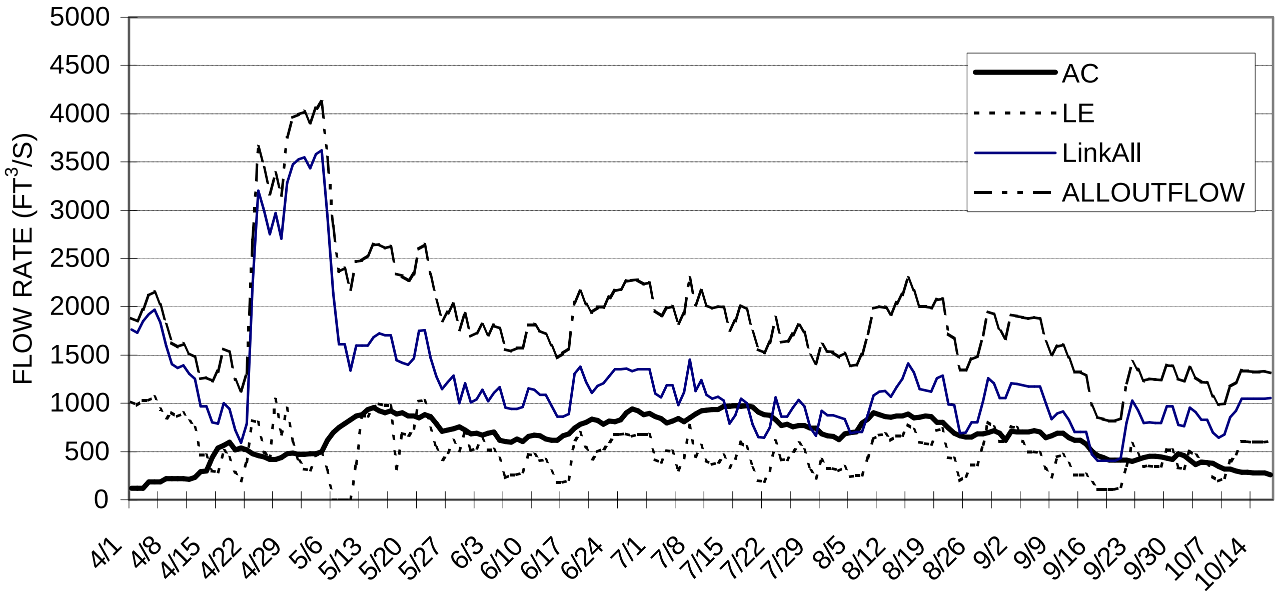


Figure 18. 1998 weekly debris composition (A - TU: Tules (bulrush & cattails), WD: Woody debris, LVS: Leaves, GR: Grasses, and AQ: Aquatic macrophytes) and volume (gal.) removed at twice daily screw trap checl Squares indicate days the A-Canal log boom was cleaned, which increased debris loading. Large values June 22 were likely due to the opening of two additional headwork gates.

A) 1997 average daily A-canal and total Link River flow rates



B) 1998 average daily A-canal and total Link River flow rates

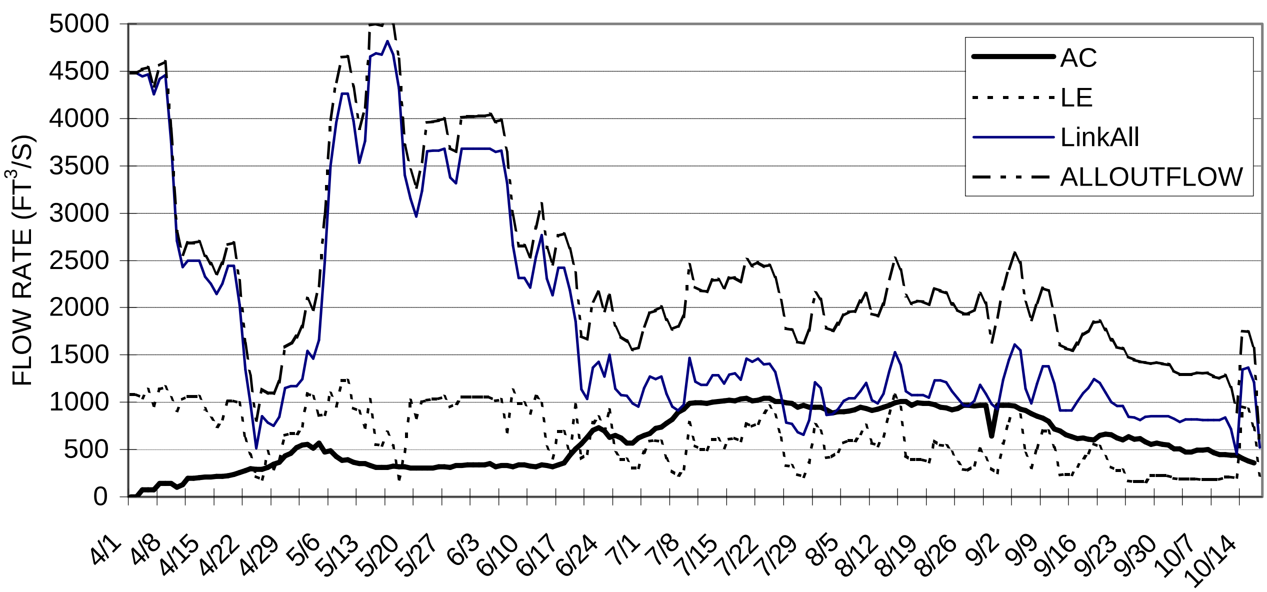


Figure 19. 1997 (A) and 1998 (B) A-Canal (AC), Link River eastside canal (LE), Link River pooled flow (Link River and both powerhouses; LinkAll), and all lake outflows combined (ALL). Values are reported as mean daily flow rates (ft^3/s).

TABLES

Species	Code	Common name	Latin name
	BC	Blue chub	*Gila coerulea*
	BBH	Brown bullhead	*Ameirus nebulosus*
	CY	Unknown minnow	Cyprinidae
	DT	Destroyed	**-**
	FH	Fathead minnow	*Pimephales promelas*
	GU	Gila unknown	*Gila* sp.
	KS	Klamath Lake sculpin	*Cottus princeps*
	KL	Klamath largescale sucker	*Catostomus snyderi*
	LMP	Lamprey unknown	*Lampetra* sp.
	LR	Lost River sucker	*Deltistes luxatus*
	MS	Marbled sculpin	*Cottus klamathensis*
	LP	Unknown sunfish	*Lepomis* sp.
	RBT	Rainbow trout (redband)	*Onchorhynchus mykiss*
	SC	Sculpin unknown (KS or SS)	*Cottus* sp.
	SN	Shortnose sucker	*Chamistes brevirostris*
	SS	Slender sculpin	*Cottus tenuis*
	SD	Speckled dace	*Rhinichthys osculus*
	SAll	Suckers, all species	Catostomidae
	SU	Sucker, unknown species	Catostomidae
	TC	Tui chub	*Gila bicolor*
	UN	Unknown species	**-**
	YP	Yellow perch	*Perca flavescens*

Disposition	Code	Explanation
	D	Dead
	A	Alive

Condition	Code	Explanation
	BLB	Blind both
	BLL	Blind left
	BLR	Blind right
	C	Columnaris
	CD	Caudal fin destroyed
	E	Eyes (e.g. adult lamprey)
	F	Fungus
	HF	Half of fish
	JD	Jaw destroyed
	L	*Lernaea* sp.
	LCH	Leech
	LW	Lamprey wound
	NE	No eyes (e.g. lamprey ammocete)
	OP	Shortened operculum
	PS	Post spawn
	RI	Ripening
	RU	Running
	S	Scales missing (descaling)
	T	Trematodes (black spot disease)
	TW	Tapeworm
	VO	Ventral open
	W	Wound

Table 1. Field codes used for species identification, fish disposition and physical condition.

A) 1997 Sampling effort			Screw trap				Fyke net			
sample dates	Mean weekly canal* flow (ft^3/s)	Total weekly canal discharge (100 acre ft.)	hours fished	sample volume (100 acre ft.)	all fish	S-All	hours fished	sample volume 100 acre ft.	all fish	S-All
5/12-18	920	128	142	8.1	1105	49				
5/19-25	840	117	167	9.0	794	49				
5/26-6/1	720	100	117	5.6	652	41	sampling starts 6/30/1999			
6/2-8	634	88	0	0.0	0	0				
6/9-15	641	89	110	4.8	700	25				
6/16-22	773	107	169	8.5	876	43				
6/23-29	868	120	165	9.0	339	42				
6/30-7/6	841	117	168	9.0	481	51	156	19.6	25	12
7/7-13	911	127	169	9.5	335	38	168	22.4	19	9
7/14-20	949	132	325	8.4	277	11	167	22.7	31	10
7/21-27	798	111	168	8.7	779	72	168	20.4	51	21
7/28-8/3	688	96	168	7.8	1124	137	167	18.6	92	29
8/4-10	800	111	168	8.6	3299	864	167	20.5	183	68
8/11-17	868	120	122	9.1	4231	874	161	20.8	266	48
8/18-24	755	105	169	8.4	3052	339	166	19.4	664	45
8/25-31	682	95	168	7.7	2802	234	165	18.2	506	32
9/1-7	702	97	120	5.6	2096	188	119	13.5	210	16
9/8-14	659	92	107	4.9	2627	118	107	11.6	88	10
9/15-21	452	63	114	3.8	870	35	107	8.2	29	7
9/22-28	428	59	107	3.5	1108	11	107	8.1	28	3
9/29-10/5	428	59	107	3.5	1056	14	107	8.0	28	5
10/6-12	333	46	107	2.9	1168	3	107	6.1	5	0
10/13-14	281	39	35	0.8	365	1	24	1.2	3	1
Totals		2218	3191	147.4	30136	3239	2162	239.2	2228	316

B) 1998 Sampling effort			Screw trap				Fyke net			
sample dates	Mean weekly canal* flow (ft^3/s)	Total weekly canal discharge (100 acre ft.)	hours fished	sample volume (100 acre ft.)	all fish	S-All	hours fished	sample volume 100 acre ft.	all fish	S-All
4/22-4/26	293	41	49	1.2	306	0	75	3.8	4	0
4/27-5/3	456	63	103	3.5	946	0	103	6.4	26	1
5/4-5/10	482	67	115	4.1	703	0	116	9.5	13	0
5/11-5/17	338	47	118	3.2	682	1	118	6.8	4	0
5/18-5/24	311	43	120	3.1	790	1	118	6.3	4	0
5/25-5/31	318	44	110	2.9	751	2	115	6.4	3	0
6/1-6/7	338	47	115	3.2	908	3	118	6.9	17	0
6/8-6/14	329	46	117	3.2	821	0	118	7.9	21	0
6/15-6/21	422	59	118	3.8	820	5	118	9.0	19	0
6/22-6/28	665	92	117	5.3	614	4	117	12.8	37	1
6/29-7/5	649	90	90	3.9	1343	37	85	9.2	15	1
7/6-7/12	947	132	113	6.5	705	39	94	12.8	19	2
7/13-7/19	1019	142	66	4.1	830	72	96	13.6	30	8
7/20-7/26	1022	142	121	7.5	1953	299	94	13.4	46	14
7/27-8/2	954	132	116	6.8	1171	147	22	3.0	25	2
8/3-8/9	908	126	106	6.0	6517	704	104	13.7	180	10
8/10-8/16	960	133	95	5.6	3714	1253	95	13.1	72	6
8/17-8/23	985	137	95	5.8	3245	1773	94	13.0	54	7
8/24-8/30	960	133	95	5.6	5571	2953	96	13.1	62	10
8/31-9/6	964	134	81	4.8	5481	977	83	11.2	131	9
9/7-9/13	765	106	71	3.6	3174	744	71	8.4	18	5
9/14-9/20	611	85	95	4.0	9052	521	72	7.5	39	2
9/21-9/27	619	86	95	4.1	2504	183	72	7.5	17	1
9/28-10/4	542	75	117	4.5	2071	56	70	6.9	13	1
10/5-10/11	480	67	118	4.2	1378	19	72	6.3	1	0
10/12-10/14	426	59	62	2.0	344	6	62	4.4	3	0
Totals		2327	2615	112.5	56394	9799	2395	233.1	873	80

Table 2. Sampling effort and total catch summary for 1997(A) and 1998 (B) screw trap and fyke net surveys. "All fish' includes only those$\geq$35 mm FL (considered the lower size limit for consistent capture in the screw trap). *Canal flow rate data was provided on a daily basis by the Klamath Irrigation District (KID

A) 1997 screw trap

	Hours	*canal	Species Catch											Total	
Dates	fished	ft^3/s	BC	FH	LMP	LR	MS	RBT	SC	SN	SU	TC	YP	fish	S-All
5/12-18	142.0	920	810	34	6	2	5	8	5	8	39	187	1	1105	49
5/19-25	166.5	840	546	42	1	0	30	6	8	0	49	112	0	794	49
5/26-6/1	117.0	720	426	46	0	0	15	0	5	0	41	119	0	652	41
6/2-8	0.0	634	0	0	0	0	0	0	0	0	0	0	0	0	0
6/9-15	110.0	641	504	57	0	0	6	1	8	0	25	99	0	700	25
6/16-22	168.7	773	588	50	0	0	15	0	4	0	43	172	4	876	43
6/23-29	164.6	868	199	9	0	7	18	0	8	3	32	60	3	339	42
6/30-7/6	168.0	841	278	10	1	3	17	2	12	4	44	110	0	481	51
7/7-13	168.6	911	148	9	0	0	9	0	5	0	38	126	0	335	38
7/14-20	324.6	949	128	6	0	0	13	1	14	0	11	99	5	277	11
7/21-27	167.7	798	242	18	0	0	40	0	168	0	72	186	53	779	72
7/28-8/3	168.1	688	236	30	0	0	11	1	114	0	137	504	91	1124	137
8/4-10	167.8	800	850	182	0	0	83	0	483	0	864	800	37	3299	864
8/11-17	121.9	868	1695	112	0	0	374	0	260	0	874	896	20	4231	874
8/18-24	169.3	755	1577	79	0	0	249	0	32	0	339	772	4	3052	339
8/25-31	168.0	682	1658	102	0	0	189	0	19	0	234	597	3	2802	234
9/1-7	120.2	702	1058	102	0	0	112	0	5	0	188	626	5	2096	188
9/8-14	107.4	659	1498	289	0	0	17	0	3	0	118	680	22	2627	118
9/15-21	113.6	452	639	34	0	0	2	0	0	0	35	154	6	870	35
9/22-28	107.1	428	834	52	0	0	2	0	3	0	11	176	30	1108	11
9/29-10/5	107.5	428	827	26	0	0	8	0	7	0	14	157	17	1056	14
10/6-12	107.0	333	1054	20	0	0	2	0	10	0	3	54	25	1168	3
10/13-14	35.0	281	330	14	0	0	0	0	2	0	1	17	1	365	1
	Totals		**16125**	**1323**	**8**	**12**	**1217**	**19**	**1175**	**15**	**3212**	**6703**	**327**	**30136**	**3239**
	yearly percentage		54%	4%	0%	0%	4%	0%	4%	0%	11%	22%	1%		11%

B) 1998 screw trap

	Hours	*canal	Species Catch													Total	
Dates	fished	ft^3/s	BBH	BC	FH	KL	LMP	LR	LP	MS	RBT	SC	SN	SU	TC	YP	fish	S-All
4/22-26	49.2	293	0	148	143	0	0	0	0	0	0	0	0	0	13	2	306	0
4/27-5/3	102.6	456	0	810	110	0	1	0	0	3	1	0	0	0	19	2	946	0
5/4-10	115.5	482	0	636	31	0	0	0	0	2	2	2	0	0	30	0	703	0
5/11-17	117.6	338	0	634	24	0	0	0	0	1	0	0	0	1	22	0	682	1
5/18-24	119.8	311	0	721	44	0	0	0	0	0	0	0	0	1	24	0	790	1
5/25-31	110.0	318	0	693	28	0	2	0	0	2	0	0	0	2	24	0	751	2
6/1-7	114.9	338	0	778	57	1	2	0	0	1	1	1	1	1	65	0	908	3
6/8-14	117.1	329	0	716	42	0	0	0	0	2	2	4	0	0	55	0	821	0
6/15-21	117.7	422	0	614	97	1	0	0	1	2	1	6	1	2	95	0	820	5
6/22-28	116.7	665	0	444	60	1	0	0	0	7	0	4	2	1	95	0	614	4
6/29-7/5	89.8	649	0	756	303	5	0	0	1	14	0	16	3	28	211	6	1343	37
7/6-12	112.6	947	0	206	77	3	0	0	2	10	0	11	1	33	128	234	705	39
7/13-19	66.5	1019	0	138	61	2	0	0	0	13	0	33	6	64	71	442	830	72
7/20-26	120.5	1022	0	180	71	2	0	0	2	18	0	425	6	289	119	841	1953	299
7/27-8/2	115.8	954	0	102	33	2	0	0	0	14	0	556	7	138	176	143	1171	147
8/3-9	106.5	908	0	801	1081	0	3	0	5	20	0	2109	11	688	1366	433	6517	704
8/10-16	94.6	960	0	241	777	1	0	0	0	26	0	992	10	1242	388	37	3714	1253
8/17-23	94.9	985	0	133	540	1	0	0	0	172	0	406	6	1766	164	57	3245	1773
8/24-30	94.8	960	1	390	1283	1	0	0	0	38	0	432	1	2951	424	50	5571	2953
8/31-9/6	80.7	964	0	732	2249	1	0	3	0	31	0	770	0	976	716	3	5481	977
9/7-13	70.8	765	0	477	1343	0	0	12	0	9	1	258	1	743	326	4	3174	744
9/14-20	95.0	611	0	1341	6385	0	0	12	0	22	0	33	2	519	727	11	9052	521
9/21-27	95.4	619	0	748	1346	0	0	5	0	7	0	16	0	183	189	10	2504	183
9/28-10/4	116.5	542	0	933	936	0	0	10	0	3	0	13	0	56	111	9	2071	56
10/5-11	117.9	480	0	575	715	0	0	4	0	8	0	7	1	18	47	3	1378	19
10/12-14	61.8	426	0	218	82	0	0	2	1	1	0	5	0	5	30	0	344	6
	Totals		**1**	**14165**	**17918**	**21**	**8**	**48**	**12**	**426**	**8**	**6099**	**59**	**9707**	**5635**	**2287**	**56394**	**9799**
	yearly percentage		0%	25%	32%	0%	0%	0%	0%	1%	0%	11%	0%	17%	10%	4%		17%

Table 3. 1997 (A) and 1998 (B) screw trap weekly sampling summary by species. S-All represents all sucker species combined. Canal flow data are weekly averages. (Table 1 includes species codes.)

A) 1997 fyke net

	Hours	canal	Species catch							
Dates	**fished**	**ft3/s**	**BBH**	**BC**	**MS**	**SC**	**SU**	**TC**	**UN**	**Total**
6/30-7/6	156	841	0	4	0	0	12	9	0	25
7/7-13	168	911	0	4	0	0	9	6	0	19
7/14-20	167	949	0	13	0	0	10	8	0	31
7/21-27	167	798	0	10	0	0	21	20	0	51
7/28-8/3	144	688	0	23	0	0	29	40	0	92
8/4-10	166	800	1	60	3	1	68	50	0	183
8/11-17	163	868	0	103	20	0	48	86	9	266
8/18-24	165	755	0	430	4	0	45	177	8	664
8/25-31	165	682	0	346	0	0	32	128	0	506
9/1-7	95	702	0	152	0	0	16	42	0	210
9/8-14	106	659	0	55	0	0	10	23	0	88
9/15-21	107	452	0	15	0	0	7	7	0	29
9/22-28	107	428	0	20	0	0	3	5	0	28
9/29-10/5	107	428	0	18	0	0	5	5	0	28
10/6-12	107	333	0	4	0	0	0	1	0	5
10/13-14	24	281	0	1	0	0	1	1	0	3
	Totals		1	1258	27	1	316	608	17	2228
	yearly percentage		0%	56%	1%	0%	14%	27%	1%	

B) 1998 fyke net

	Hours	canal	Species catch													
Dates	**fished**	**ft3/s**	**BBH**	**BC**	**FH**	**KL**	**LMP**	**LR**	**MS**	**SN**	**SU**	**TC**	**UN**	**YP**	**Total**	**SAll**
4/22-26	75.2	286	0	1	0	0	1	0	0	0	0	2	0	0	4	0
4/27-5/3	102.9	476	0	20	1	0	1	0	0	0	1	2	0	1	26	1
5/4-10	115.6	469	0	8	0	0	0	0	1	0	0	4	0	0	13	0
5/11-17	117.8	332	0	3	0	0	0	0	0	0	0	1	0	0	4	0
5/18-24	117.8	309	0	3	0	0	0	0	0	0	0	1	0	0	4	0
5/25-31	114.5	320	0	2	0	0	0	0	0	0	0	1	0	0	3	0
6/1-7	118.1	337	0	12	2	0	0	0	0	0	0	3	0	0	17	0
6/8-14	117.9	390	1	12	0	0	0	0	0	0	0	8	0	0	21	0
6/15-21	117.8	442	0	10	0	0	0	0	1	0	0	8	0	0	19	0
6/22-28	117.2	665	0	23	0	0	0	0	1	1	0	12	0	0	37	1
6/29-7/5	84.9	666	0	6	0	0	0	0	0	1	0	8	0	0	15	1
7/6-12	114.0	960	0	9	0	0	0	0	0	2	0	8	0	0	19	2
7/13-19	110.0	1016	0	17	0	3	0	0	1	3	2	4	0	0	30	8
7/20-26	106.5	1022	0	12	0	0	0	1	1	12	1	18	1	0	46	14
7/27-8/2	22.0	945	0	13	0	1	0	0	1	1	0	9	0	0	25	2
8/3-9	103.5	912	0	69	0	2	0	0	0	6	2	101	0	0	180	10
8/10-16	95.3	969	0	27	0	1	0	0	0	5	0	39	0	0	72	6
8/17-23	93.6	981	0	13	0	1	0	0	21	3	3	12	0	1	54	7
8/24-30	95.5	961	0	19	0	0	0	0	4	0	10	27	1	1	62	10
8/31-9/6	82.5	953	0	33	0	0	0	0	2	0	9	87	0	0	131	9
9/7-13	71.0	762	0	7	0	0	0	0	0	1	4	6	0	0	18	5
9/14-20	95.8	615	0	16	0	0	0	0	1	0	2	20	0	0	39	2
9/21-27	95.4	618	0	11	0	0	0	0	0	0	1	4	0	1	17	1
9/28-10/4	116.3	537	0	6	0	0	0	0	0	1	0	6	0	0	13	1
10/5-11	118.4	480	0	1	0	0	0	0	0	0	0	0	0	0	1	0
10/12-14	61.9	414	0	1	0	0	0	0	0	0	0	2	0	0	3	0
	Totals		1	354	3	8	2	1	34	36	35	393	2	4	873	80
	yearly percentage		0%	41%	0%	1%	0%	0%	4%	4%	4%	45%	0%	0%		9%

Table 4. 1997 (A) and 1998 (B) fyke net weekly sampling summary by species. In 1997, all suckers were listed as SU. Canal flow data are weekly averages. (Table 1 includes species codes.)

	Species	Life stage	Ammonia ppm	Ammonia C.I.	pH pH	pH C.I	DO ppm	DO C.I.	DO % sat.	Temperature °C	Temperature C.I.	Test	Source
	LR	larval			10.45	10.43-10.48	2.1	2.0-2.2	25.8 24.9-26.8			96-h LC_{50}	Bellerud and Saiki, 1995
	LR	juvenile	0.70	0.34-0.82	10.68	10.52-11.03	1.8	1.6-1.9		30.0	29.9-30.3	96-h LC_{50}	Monda and Saiki 1993
Multiple variable test	LR	juvenile		0.45-0.88								96-h LC_{50}	Monda and Saiki 1993
	LR	juvenile					1.4					*Ambient in UKL	Martin, 1997
	LR	juvenile	0.75	0.59-0.94	9.92	9.87-9.96	1.4	1.0-2.0	19.1 13.9-26.2	31.2	30.8-31.5	96-h LC_{50}	Bellerud and Saiki 1995
1st test	SN	larval	0.75	0.73-0.77	10.3	10.0-10.7	2.3	2.2-2.4	30.3 28.9-31.6	31.9	31.9-32.0	96-h LC_{50}	Bellerud and Saiki, 1995
2nd test	SN	larval	1.4	1.24-1.68	10.5	10.12-10.83	1.7	1.6-1.8	22.3 21.0-23.6	31.4	31.2-31.6	96-h LC_{50}	Bellerud and Saiki 1995
	SN	larval	3.35									100% mortality	Bellerud and Saiki 1995
	SN	juvenile					0.69 min			32.7 max		Critical values	Castleberry and Cech 1993
	SN	juvenile			9.55 +/- 0.43							critical max	** Falter and Cech 1991
	SN	juvenile	0.34	0.14-0.73	10.50	9.82-11.0	1.5	0.6-2.4		29.4	27.8-34.1	96-h LC_{50}	Monda and Saiki 1993
	SN	juvenile	0.96	0.32-2.46	9.85	9.76-9.96	1.2	0.7-1.7	14.7 7.6-22.5	31.2	30.8-31.6	96-h LC_{50}	Bellerud and Saiki 1995

Table 5. Lost River and shortnose sucker tolerance limits for ammonia, pH, temperature, and dissolved oxygen concentrations as determined in laboratory or field testing. C.I. = 95% confidence interval. * 96-hr tests were conducted in cages in Upper Klamath Lake using multi-parameter deployable datasondes to monitor water quality. Mortality was over 90% when DO levels fell below 1.4 ppm at any time during the test. **Critical values were determined when suckers lost equilibrium.

A) 1997 indices

		Screw trap entrainment index										Fyke net entrainment index						1997
week #	dates	BC	FH	LMP	MS	RBT	SC	SU	TC	YP	Totals	BC	MS	SU	TC	Misc	Totals	totals
20	5/12-18	12731	534	94	79	126	79	770	2939	16	17,368							17368
21	5/19-25	7,193	553	13	395	79	105	646	1,476	0	10,461							10,461
22	5/26-6/1	7,403	799	0	261	0	87	712	2,068	0	11,330							11,330
23	6/2-8	8,441	936	0	187	9	119	591	1,965	0	12,248	NO FYKE NET COLLECTIONS BEFORE June 30, 1997						12,248
24	6/9-15	9,480	1,072	0	113	19	150	470	1,862	0	13,167							13,167
25	6/16-22	7,445	633	0	190	0	51	544	2,178	51	11,091							11,091
26	6/23-29	2,652	120	0	240	0	107	560	800	40	4,517							4,517
27	6/30-7/6	3,608	130	13	221	26	156	662	1,428	0	6,242	25	0	76	57	0	158	6,401
28	7/7-13	1,948	118	0	118	0	66	500	1,658	0	4,409	23	0	51	34	0	107	4,516
29	7/14-20	2,013	94	0	204	16	220	173	1,557	79	4,356	75	0	58	46	0	180	4,535
30	7/21-27	3,101	231	0	512	0	2,152	922	2,383	679	9,981	54	0	113	107	0	274	10,254
31	7/28-8/3	2,883	366	0	134	12	1,393	1,673	6,156	1,112	13,730	117	0	147	203	0	467	14,196
32	8/4-10	11,014	2,358	0	1,075	0	6,259	11,196	10,366	479	42,748	326	16	370	272	11	995	43,743
33	8/11-17	22,856	1,510	0	5,043	0	3,506	11,785	12,082	270	57,051	552	107	257	461	48	1,426	58,477
34	8/18-24	19,729	988	0	3,115	0	400	4,241	9,658	50	38,183	2204	21	231	907	41	3,404	41,587
35	8/25-31	20,330	1,251	0	2,318	0	233	2,869	7,320	37	34,358	1716	0	159	635	0	2,509	36,867
36	9/1-7	19,273	1,858	0	2,040	0	91	3,425	11,403	91	38,181	951	0	100	263	0	1,313	39,494
37	9/8-14	26,993	5,208	0	306	0	54	2,126	12,253	396	47,336	374	0	68	156	0	598	47,934
38	9/15-21	10,911	581	0	34	0	0	598	2,630	102	14,856	101	0	47	47	0	196	15,052
39	9/22-28	15,563	970	0	37	0	56	205	3,284	560	20,676	156	0	23	39	0	219	20,895
40	9/29-10/5	14,474	455	0	140	0	123	245	2,748	298	18,482	107	0	30	30	0	167	18,649
41	10/6-12	16,313	310	0	31	0	155	46	836	387	18,078	33	0	0	8	0	41	18,119
42	10/13-14	4,177	177	0	0	0	25	13	215	13	4,620	5	0	5	5	0	14	4,634
		250,531	21,254	120	16,794	287	15,585	44,974	99,265	4,658	453,469	6,819	144	1,734	3,270	100	12,067	465,536

B) 1998 indices

		Screw trap entrainment index										Fyke net entrainment index						1998
week	Dates	BC	FH	LP	MS	S-All	SC	TC	YP	Misc	Totals	BC	MS	S-All	TC	Misc	Totals	totals
17	4/21-4/26	4,218	4,076	0	0	0	0	371	57	0	8,721	17	0	0	34	17	67	8,789
18	4/27-5/3	15,673	2,128	0	58	0	0	368	39	38	18,304	149	0	7	15	22	194	18,498
19	5/4-5/10	10,843	529	0	34	0	34	511	0	34	11,985	51	6	0	25	0	82	12,067
20	5/11-5/17	9,884	374	0	16	16	0	343	0	0	10,632	18	0	0	6	0	25	10,657
21	5/18-5/24	10,949	668	0	0	15	0	364	0	0	11,996	15	0	0	5	0	20	12,016
22	5/25-5/31	9,396	380	0	27	27	0	325	0	27	10,182	14	0	0	7	0	21	10,203
23	6/1-6/7	10,517	771	0	14	41	14	879	0	41	12,275	111	0	0	28	18	157	12,431
24	6/8-6/14	9,807	575	0	27	0	55	753	0	27	11,245	71	0	0	47	6	124	11,369
25	6/15-6/21	10,467	1,654	0	34	85	102	1,620	0	17	13,979	103	10	0	82	0	195	14,174
26	6/22-6/28	10,891	1,472	0	172	98	98	2,330	0	0	15,061	127	6	6	66	0	204	15,265
27	6/29-7/5	16,086	6,447	0	298	787	340	4,490	128	0	28,576	46	0	8	62	0	116	28,692
28	7/6-7/12	4,675	1,748	0	227	885	250	2,905	5,311	0	16,000	91	0	20	81	0	193	16,193
29	7/13-7/19	4,338	1,917	0	409	2,263	1,037	2,232	13,894	0	26,090	182	11	85	43	0	320	26,410
30	7/20-7/26	2,927	1,154	0	293	4,861	6,910	1,935	13,674	0	31,753	142	12	165	212	12	543	32,296
31	7/27-8/2	3,230	1,045	0	443	4,655	17,606	5,573	4,528	0	37,081	490	38	75	339	0	942	38,023
32	8/3-8/9	14,920	20,135	0	373	13,113	39,283	25,443	8,065	56	121,387	569	0	83	833	0	1,485	122,873
33	8/10-8/16	5,574	17,971	0	601	28,980	22,943	8,974	856	0	85,898	271	0	60	392	0	724	86,622
34	8/17-8/23	3,573	14,506	0	4,620	47,628	10,906	4,406	1,531	0	87,171	144	233	78	133	11	598	87,769
35	8/24-8/30	9,783	32,185	0	953	74,078	10,837	10,636	1,254	25	139,751	232	49	122	329	24	756	140,507
36	8/31-9/6	20,813	63,947	85	881	27,780	21,894	20,358	85	0	155,845	320	19	87	843	0	1,269	157,114
37	9/7-9/13	16,798	47,294	423	317	26,200	9,085	11,480	141	35	111,772	79	0	56	68	0	203	111,975
38	9/14-9/20	23,103	110,001	207	379	8,976	569	12,525	190	0	155,948	125	8	16	156	0	304	156,252
39	9/21-9/27	16,133	29,030	108	151	3,947	345	4,076	216	0	54,006	86	0	8	31	8	132	54,138
40	9/28-10/4	14,603	14,650	157	47	876	203	1,737	141	0	32,415	34	0	6	34	0	73	32,488
41	10/5-10/11	7,935	9,867	55	110	262	97	649	41	0	19,016	10	0	0	0	0	10	19,026
42	10/12-10/14	2,496	939	23	11	69	57	344	0	0	3,939	5	0	0	10	0	14	3,953
		269,630	385,462	1,057	10,496	245,642	142,666	125,627	50,150	301	1,231,030	3,499	391	882	3,881	119	8,771	1,239,801

Table 6. 1997 (A) and 1998 (B) weekly A-Canal entrainment indices by sampling method and species.
Misc. category includes rare fyke net catches - BBH, SC, LMP, YP, or FH.

A) 1997 sucker entrainment summary

dates	hours fished	% canal sampled	S-All ST catch	S-All FN catch	Total suckers	S-All index from ST	S-All index from FN	Total S-All index
5/12-18	142.0	7.5%	49	ND	49	770	ND	770
5/19-25	166.5	7.7%	49	ND	49	646	ND	646
5/26-6/1	117.0	8.0%	41	ND	41	712	ND	712
6/2-8	0.0	0.0%	0	ND	0	591	ND	591
6/9-15	110.0	8.3%	25	ND	25	470	ND	470
6/16-22	168.7	7.9%	43	ND	43	544	ND	544
6/23-29	164.6	7.6%	42	ND	42	560	ND	560
6/30-7/6	168.0	7.7%	51	12	63	662	76	738
7/7-13	168.6	7.5%	38	9	47	500	51	551
7/14-20	324.6	7.4%	11	10	21	173	58	231
7/21-27	167.7	7.8%	72	21	93	922	113	1035
7/28-8/3	168.1	8.1%	137	29	166	1,673	147	1821
8/4-10	167.8	7.8%	864	68	932	11,196	370	11565
8/11-17	121.9	7.6%	874	48	922	11,785	257	12042
8/18-24	169.3	7.9%	339	45	384	4,241	231	4472
8/25-31	168.0	8.2%	234	32	266	2,869	159	3028
9/1-7	120.2	8.1%	188	16	204	3,425	100	3525
9/8-14	107.4	8.2%	118	10	128	2,126	68	2194
9/15-21	113.6	9.2%	35	7	42	598	47	645
9/22-28	107.1	9.3%	11	3	14	205	23	229
9/29-10/5	107.5	9.3%	14	5	19	245	30	275
10/6-12	107.0	10.0%	3	0	3	46	0	46
10/13-14	35.0	10.5%	1	1	2	13	5	17
			3,239	316	3,555	44,974	1,734	46,708

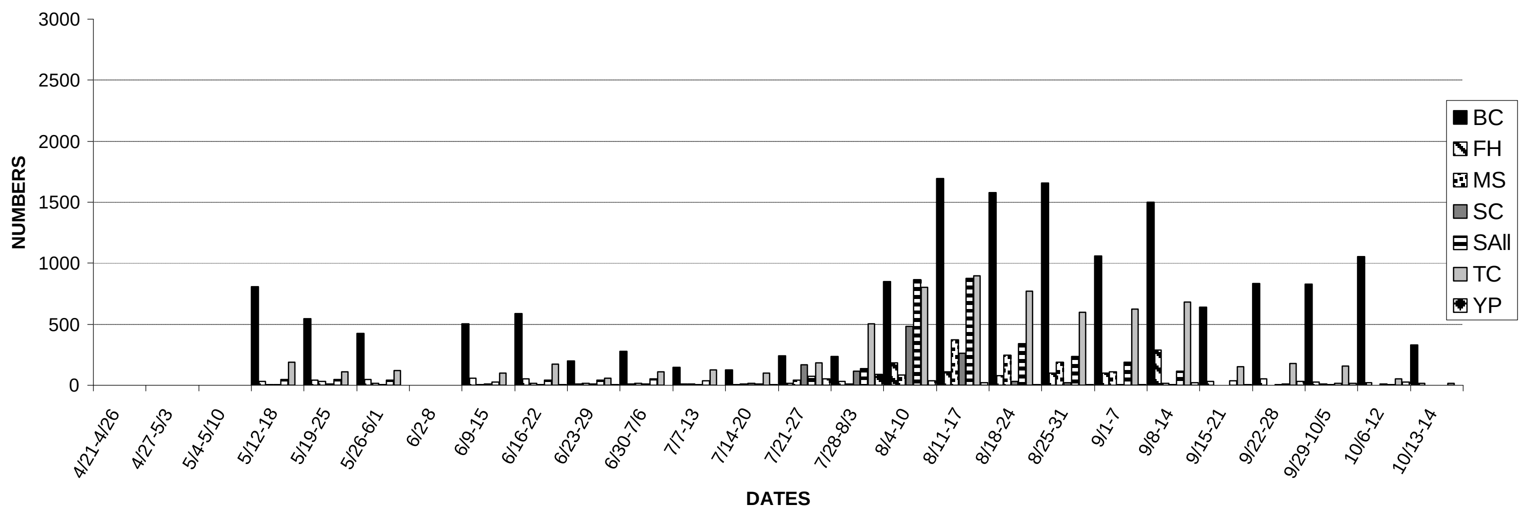
B) 1998 sucker entrainment summary

dates	hours fished	% canal sampled	S-All ST catch	S-All FN catch	Total suckers	S-All index from ST	S-All index from FN	Total S-All index
4/21-4/26	49.2	10.3%	0	0	0	0	0	0
4/27-5/3	102.6	9.1%	0	1	1	0	7	7
5/4-5/10	115.5	8.9%	0	0	0	0	0	0
5/11-5/17	117.6	9.9%	1	0	1	16	0	16
5/18-5/24	119.8	10.1%	1	0	1	15	0	15
5/25-5/31	110.0	10.0%	2	0	2	27	0	27
6/1-6/7	114.9	9.9%	3	0	3	41	0	41
6/8-6/14	117.1	10.0%	0	0	0	0	0	0
6/15-6/21	117.7	9.3%	5	0	5	85	0	85
6/22-6/28	116.7	8.2%	4	1	5	98	6	104
6/29-7/5	89.8	8.3%	37	1	38	787	8	795
7/6-7/12	112.6	7.5%	39	2	41	885	20	905
7/13-7/19	66.5	7.3%	72	8	80	2,263	85	2348
7/20-7/26	120.5	7.3%	299	14	313	4,861	165	5026
7/27-8/2	115.8	7.4%	147	2	149	4,655	75	4730
8/3-8/9	106.5	7.5%	704	10	714	13,113	83	13196
8/10-8/16	94.6	7.4%	1253	6	1259	28,980	60	29040
8/17-8/23	94.9	7.4%	1773	7	1780	47,628	78	47706
8/24-8/30	94.8	7.4%	2953	10	2963	74,078	122	74200
8/31-9/6	80.7	7.4%	977	9	986	27,780	87	27867
9/7-9/13	70.8	7.9%	744	5	749	26,200	56	26256
9/14-9/20	95.0	8.4%	521	2	523	8,976	16	8992
9/21-9/27	95.4	8.4%	183	1	184	3,947	8	3955
9/28-10/4	116.5	8.7%	56	1	57	876	6	882
10/5-10/11	117.9	9.0%	19	0	19	262	0	262
10/12-10/14	61.8	9.3%	6	0	6	69	0	69
			9,799	80	9,879	245,642	882	246,524

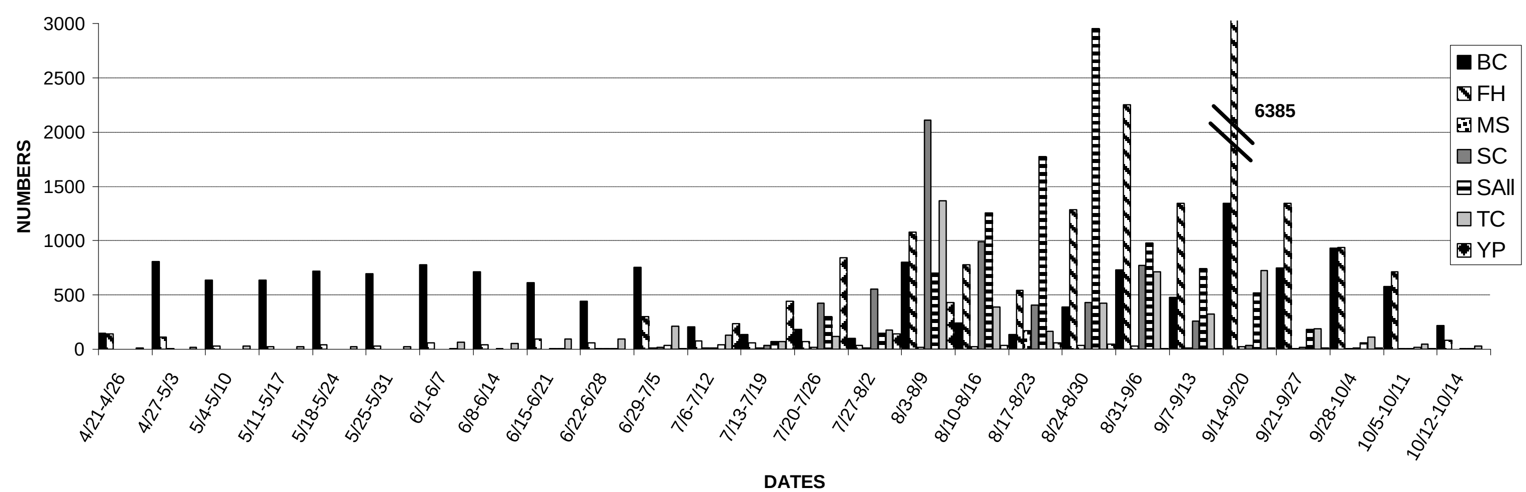
Table 7. 1997 (A) and 1998 (B) weekly screw trap and fyke net sucker entrainment indices including hours fished and percent of the canal sampled.

APPENDIX FIGURES

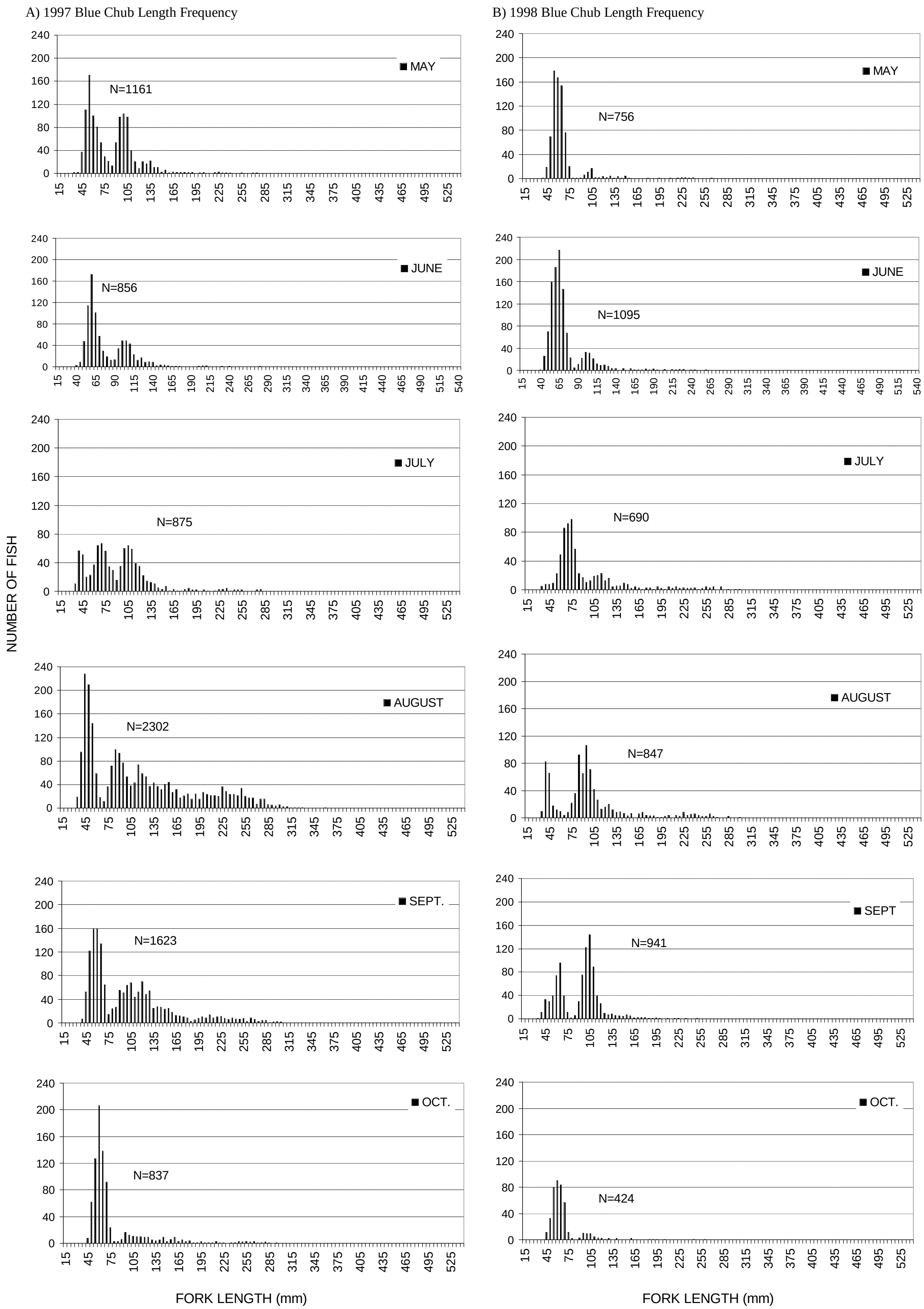
A) 1997 total weekly screw trap catch - by species



B) 1998 total weekly screw trap catch - by species



Appendix Figure A1. 1997 (A) and 1998 (B) total weekly screw trap catches by species.



Appendix Figure A2. 1997 (A) and 1998 (B) monthly screw trap blue chub length frequency histograms. Since blue chubs were often subsampled, 'N' = the number measured.